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The evaluation of a central heating system for a government facility

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THE EVALUATION OF A CENTRAL HEATING SYSTEM FOR A GOVERNMENT FACILITY

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THE EVALUATION OF A CENTRAL HEATING SYSTEM FOR A GOVERNMENT FACILITY

by

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ABSTRACT

The purpose of this paper is to evaluate an existing government owned and operated central heating system to determine if a more economical method of providing steam requirements can be determined. Five possible solutions are considered. Through cost comparison, the most economic solution is determined, first on the basis of total cost to own and operate, and then on the basis of cost to operate only.

The most economic solution is the operation of the existing system with a reduction of personnel.

PART I.

INTRODUCTION

The evaluation of a central heating system for a government facility presents the same problems as the evaluation of a similar privately owned system. Costs must be calculated for several alternatives. Cost of these alternatives must be evaluated considering the cost of both ownership and operation.

The basis for determining costs, especially fixed costs, is an area in which the government has deviated from private industry. Recently in a move to place government industrial operations on standards similar to those of private industry, the costs chargeable to the government are being calculated on the same basis as in industry.

Under study is a system which provides the steam requirements to a government owned and operated facility located in "Upstate" New York. The steam is provided by a central plant, which consists of two 50,000 lb/hr boilers (installed in 1946) and two 100,000 lb/hr boilers (installed in 1956). Saturated steam at 115 psig is generated by the automatic burning of No. 6 fuel oil and distributed to the points of use.

In 1946, the distribution system was rehabilitated and placed in a like new condition. A further rehabilitation occurred in 1956, along with the installation of additional boiler capacity. This system now provides steam to 47 buildings and there are no additional buildings planned.

The system operates on a 24 hour a day schedule, employing 25 civil service personnel.

This evaluation considers the following alternatives:

(1) Continued operation of the existing system,

(2) Operation of the existing system with a reduction in personnel,

(3) Installation of a new distribution system,

(4) Installation in the existing system of an automatic boiler for the process load in the summer,

(5) Rehabilitation of deteriorated steam line insulation.

PART II.

DETERMINATION OF STEAM LOADS AND STEAM GENERATION

In estimating steam requirements building loads must be calculated. (Each building load consists of heating, hot water, and process steam loads.) In addition, auxiliary load and line loss is determined to estimate the steam generation.

Building Loads

Heating Load*

Heating load is estimated by grouping buildings of similar heat loss characteristics together. The heat loss from one building of each group is calculated in detail. Then, with gross volume as a parameter, the heat loss from other buildings within the group is evaluated. To estimate heat loss for the housing group, net heated floor area is the parameter. Hourly design heating loads are converted to annual steam consumption by the degree day method. Industrial degree days (55°F base) are used for the storage areas and the conventional 65° base for other areas.

Hot Water

Maximum hot water load is obtained from presently installed equipment which is adequate for the service required. Annual steam consumption for hot water heating considers both installed capacity and a

*Heating Ventilating Air Conditioning Guide. 1958. Vol. 36, Ch. 12 and Ch. 18. Calculation of heating loads is given in Appendix A.

demand factor.*

Process Steam Load

Annual process steam consumption is estimated from a typical load curve for summer weekdays. Peak loads are determined by considering installed equipment.

Steam Plant Loading

Line Losses

Line losses are evaluated by use of a typical summer weekend load curve for the existing system. To determine line losses for new or re-insulated lines, manufacturer's test data**is utilized.

Auxiliary Load

The auxiliary load is determined through the use of heat balance calculations on pieces of plant equipment which consume steam.

Steam Generated

Steam generated is the sum of the previously mentioned loads: (1) heating load, (2) hot water load, (3) process steam load, (4) line losses, and (5) auxiliary steam loads. These estimates are reasonable, in that they compare favorably with records of steam generated by the boiler plant during the year 1959. Estimated steam requirements compare with actual steam generation within 6%.

*ibid. p. 1208.

**Johns-Manville A. I. A. File No. 37-D-2. p. 11-19.

Table I Steam Loads (lbs. per hr.)

Load	Historical 1959	Alternative 1 & 2	Alternative 3	Alternative 4	Alternative 5
Line loss	47,304,000	47,304,000	10,316,788	28,844,856	43,967,780
Hot water	5,734,160	5,734,160	5,734,160	5,734,160	5,734,160
Process	21,708,000	21,708,000	21,708,000	21,708,000	21,708,000
Heating	167,267,490	181,931,499	181,931,499	181,931,499	181,931,499
Auxiliary	39,397,561	41,784,556	35,736,407	40,779,107	41,575,075
TOTAL	281,141,151	298,462,215	255,453,854	278,998,107	294,916,414

PART III.

DETERMINATION OF COSTS

Total annual cost is taken as the sum of the fixed cost and operating cost.

Fixed Cost

System Cost

System cost is the cost of both the steam generating plant and the distribution system. This cost is based on actual cost records when possible.

Cost of construction necessary under Alternatives 3, 4, and 5 is arrived at by considering charges for material and installation (labor, overhead, profit, insurance, etc.). Material costs are based on manufacturers' prices. By consideration of several sections where new construction is contemplated, detailed cost estimates indicate total cost may be reasonably approximated for relative evaluation purposes by considering total cost to be 2.5 times the material cost. This agrees fairly well with general costing as recommended by manufacturers of equipment.

Table II Cost of System

Description	Existing System Alt. 1	Reduced Personnel Alt. 2	New Dist. System Alt. 3	Installation of a "Summer System" Alt. 4	Rehabilitate Existing Lines Alt. 5
Cost of System					
Plant	$1,890,699.	$1,890,699.	$1,890,699.	$1,890,699.	$1,890,699.
Dist.	442,295.	442,295.	358,480.	442,295.	452,540.

Description	Existing System Alt. 1	Reduced Personnel Alt. 2	New Dist. System Alt. 3	Installation of a "Summer System" Alt. 4	Rehabilitate Existing Lines Alt. 5
Summer System	$ 0	$ 0	$ 0	$ 58,295.	$ 0
TOTAL	$2,332,994.	$2,332,994.	$2,249,179.	$2,391,289.	$2,343,139.
Capital investment required	$ 0	$ 0	$ 358,480.	$ 58,295.	$ 10,245.

Fixed Cost

Fixed costs consist of depreciation, interest, taxes, and insurance. These costs are calculated on the basis of capital investment and the assumption that salvage value of the property is equivalent to cost of removal.

Table III Fixed Cost Rates

Cost	Rate	Source
Depreciation	20 year - straight line	Treasury Bulletin F
Interest	4½%	current government rate
Taxes	$68.54/$1000.	rate in local area
Insurance	$0.044/$100.	New York Fire Insurance Rating Organization

Operating Costs

Operating costs are made up of charges for fuel, water, electric power, other supplies, and personnel for operations and maintenance. These figures result from 1959 costs.

Table IV Summary of Fixed and Operating Costs*

Item of Cost	1959	Alt. 2	Alt. 3	Alt. 4	Alt. 5
Fixed costs					
Depreciation	$116,649.	$116,649.	$112,459.	$119,564.	$117,157.
Interest	55,117.	55,117.	53,137.	56,494.	55,357.
Taxes	159,903.	159,903.	154,158.	163,898.	160,599.
Insurance	1,027.	1,027.	990.	1,052.	1,031.
TOTAL	$332,696.	$332,696.	$320,744.	$341,008.	$334,144.
Operating costs					
Fuel	$137,039.	$145,678.	$124,684.	$136,154.	$143,922.
Water	2,684.	2,846.	2,436.	2,661.	2,813.
Electricity	2,105.	2,238.	1,915.	2,092.	2,212.
Operation supplies	1,500.	1,500.	1,500.	1,500.	1,500.
Operations labor	95,229.	50,966.	50,966.	43,373.	50,966.
Maint. labor	16,687.	16,687.	16,687.	19,205.	16,687.
Maint. materials	6,000.	6,000.	6,000.	6,000.	6,000.
Supervision & Clerical	12,768.	12,768.	12,768.	12,768.	12,768.
Misc. materials	200.	200.	200.	200.	200.
TOTAL	$274,208.	$238,883.	$217,156.	$224,022.	$237,060.

*Detailed calculations in Appendixes B, C, D, E, and F.

PART IV.

DESCRIPTION OF ALTERNATIVES

Alternative 1* Continued Operation of the Existing System without Change

During the heating season, all distribution lines are utilized to supply steam requirements. Boilers are operated in pairs (one 100,000 lb/hr and one 50,000 lb/hr unit) which alternate monthly. The base load is carried by the larger unit while the second unit is used to handle peak loadings.

During the summer, only lines required for process steam distribution are kept under pressure. (Hot water service is provided by electric resistance elements installed on all tank equipment). One 50,000 lb/hr boiler provides all steam requirements during this season.

Boiler control is automatic from a central board. Buildings have various types of thermostatic control depending upon installed heating elements. Five buildings are equipped with night set-back. In addition, when extended weather forecasts indicate mild weekend weather, manual control is used to reduce steam consumption.

Twenty-five civil service personnel are employed. The operation's crew consists of five men per shift, one engineer, one senior fireman, two firemen and one steam fitter (part time) for a total of twenty. Maintenance is accomplished by three men. A plant manager and one clerk perform all management functions.

*Summary of costs is given in Table V, p. 13. Calculations are given in Appendixes B and C.

Alternative 2* Operation of the Existing System with Reduced Personnel

Operation schedule is identical to that previously described under Alternative 1.

The operations crew is reduced from five to two men per shift. This employment level is consistont with current practice in the government and private industry. Maintenance and management personnel levels are uneffected.

No capital investment is required.

Alternative 3** The Installation of a New Distribution System

During the heating season, all distribution lines are utilized to deliver the steam requirements. One 100,000 lb/hr boiler is required to meet the estimated steam requirements.

During the summer, only lines required for process steam distribution are kept under pressure. One 50,000 lb/hr is utilized to provide all steam requirements. Control utilized is identical to that indicated under Alternative 1.

Personnel level is identical to that indicated under Alternative 2.

Since the existing steam plant is utilized, no new construction within the plant is anticipated. A new distribution system replaces the existing system, which is removed for salvage value. This system is designed for the existing requirements considering that the

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*Summary of costs is given in Table V, p. 13. Calculations are in Appendix C.

**Summary of costs is given in Table V, p. 13. Calculations are given in Appendix D.

facility is fully developed.

Steam lines in industrial areas are overhead where possible. Overhead arrangement results in decreased installation and maintenance costs.

As the capital investment for a new distribution system precludes its use, the additional investment required to install an automatic boiler for summer process steam requirements can not be justified.

<u>Alternative 4* Installation in the Existing System of an Automatic Boiler for Process Load in the Summer</u>

Operations during the heating season are identical with those described under Alternative 1.

During the summer, the central steam plant remains idle and the automatic boiler installed in Building 110 is used to supply all process steam requirements. Only those sections of the system required for process steam distribution are pressurized.

Total number of personnel is reduced by one maintenance man from the level of Alternative 2. The employment of operations personnel is as follows:

(1) Heating Season - Two men per shift (one engineer and one fireman) operate the central steam plant.

(2) Summer - One engineer per shift periodically inspects the automatic boiler and the central plant. Firemen are employed on maintenance.

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*Summary of costs is given in Table V, p. 13. Calculations are in Appendix E.

An automatic boiler (15,000 lb/hr) is installed in a vacant area of Building 110 near the center of the process steam load. New steam and return lines are installed from the boiler site to Buildings 121, 122, and 123 so that a minimum of line is hot during summer. In addition, deteriorated insulation on existing lines used for process steam distribution is renewed.

A reduction of one employee, the central location for process steam generation, and reduced line losses result in a savings.

Alternative 5* Replacement of Deteriorated Insulation on the Existing System

Operation's schedule is identical to that described under Alternative 1.

Personnel requirements are identical to those described under Alternative 2.

Approximately 50% of the interior lines installed in 1946 have non-existent or deteriorated insulation. The work consists of removing existing deteriorated insulation and reinsulating.

Savings in operating cost is effected by a reduction in line losses.

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*Summary of costs is given in Table V, p. 13. Calculations are given in Appendix F.

PART V.

SUMMARY OF RESULTS

Table V Comparison of Annual Costs
(fixed costs on the sunk cost principle)

Item of Cost	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5
Fixed cost	$216,047.	$216,047.	$236,658.	$224,359.	$217,495.
Operating cost	283,146.	238,883.	217,156.	224,022.	237,060.
TOTAL COST	$499,193.	$454,930.	$453,814.	$448,381.	$454,555.

Table VI Comparison of Savings and Time to Amortize
(based on (A) Total Costs and (B) Operating Costs)

	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5
A. Total Costs	$499,193.	$454,930.	$453,814.	$448,381.	$454,555.
Capital to be invested	base	0	358,480.	58,295.	10,245.
Saving over Alt. 1	base	44,263.	45,379.	50,812.	44,638.
Years to amortize on savings over Alt. 2		base	300+	8.9	27
B. Operating Costs	283,146.	238,263.	217,156.	224,022.	237,060.
Saving over Alt.	base	44,263.	65,990.	59,124.	46,086.
Years to amortize on savings over Alt. 2		base	16.5	3.9	5.6

PART VI.

DISCUSSION

Boiler Capacity and Scheduling

A boiler capacity of 300,000 lb/hr is available. Examination of design requirements (210,000 lb/hr) indicates that capacity exceeds requirements. With a trend towards reduced process steam equipment and an average heating load less than the design load, a capacity of 200,000 lb/hr would be adequate. This figure has been verified by a review of plant records which indicate a recorded peak load of 118,000 lb/hr. If the plant were to be re-equipped two 25,000 lb/hr and two 75,000 lb/hr water tube boilers would be adequate. No recommendation for disposal of part of the existing capacity is considered, as installed equipment is performing satisfactorily and the capital cost has already been paid.

Boiler scheduling can result in reduction of operating expenses. Two 50,000 lb/hr and two 100,000 lb/hr units are installed in the present boiler plant. Since winter peak loading is approximately 118,000 lb/hr, one 100,000 lb/hr and one 50,000 lb/hr unit would adequately handle this steam demand. Peaks normally occur in the early morning (5 - 8 A.M.) due to clock settings on thermostats. These peaks are controllable depending on the time allowed for warm up. A somewhat longer warm up period would not affect production or comfort and would reduce peak load requirements.

In the summer one 50,000 lb/hr unit will generate steam requirements.

Equipment operation should be rotated so that all units pro-

vide equal service over life expectancy. This rotation should be on a monthly basis.

Controls

Boiler combustion controls are located on a central board. Meters, gauges, and other indicating devices are located so that one operator controls and supervises all units. Independent flame detection and other safety devices are installed and equipped with audio alarms. The existing control system is adequate and performs satisfactorily.

Buildings have thermostatic controls of various styles depending on the type of heat emitting units installed. Night set-back equipment is installed where possible. On buildings not equipped with night set-back, manual control is exercised on weekends during mild weather.

Evaluation of Cost

In evaluating cost to choose between alternatives of operation, consideration must be given to sunk costs. "A sunk cost is a past expenditure which has already occurred and must be ignored as having nothing to do with a choice between two alternatives for the future."* This in effect reduces the fixed costs of existing equipment.

In addition to total costs, time to amortize is considered when selecting the most economic solution. By policy, an amortization period of five years is considered maximum when replacing satisfactory equipment. Since Alternative 2 requires no capital investment, the total cost of this alternative is used to determine savings when calcu-

*Grant, E.L. Principles of Engineering Economy. p. 179.

lating the amortization time of the other alternatives considered.

PART VII.

CONCLUSIONS AND RECOMMENDATION

Conclusions

(1) A reduction of personnel in the existing system (Alternative 2) is the most economic solution when evaluation is on the basis of cost to own and operate.

(2) Installation of an automatic boiler in the existing system for summer process steam requirements (Alternative 4) is the most economic alternative considering operating costs only.

Recommendation

It is recommended that a reduction of seven operating personnel be accomplished and that system operation be continued on the existing schedule.

PART VIII.

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PART IX.

APPENDIX A

Calculation of Design Heat Loss

I. Basis for calculation of design heat loss

A. Outside design temperature -10°F

B. Outside wind velocity 15mph

C. Inside design temperature 70°F

D. Transmission loss

1. Exposed surfaces = (area)(coefficient)(temp. diff.)

2. Wall below grade = (area)(unit heat loss)

3. Basement floor = (area)(unit heat loss)

E. Infiltration loss = (cfh)(specific heat)(temp. diff.)

F. All coefficients, values for infiltration, and heat losses are from the "Heating, Ventilating and Air Conditioning Guide".

G. Unheated space temperature is based on a heat balance for the space concerned.

H. All losses are shown in Btu/hr.

II. Design heat loss for Building 2

A. Walls are as follows: (coefficients are indicated in parenthesis in Btu/hr-ft^2-°F)

1. Basement walls are 12" brick, insulating board and plaster on furring.(0.23)

2. Exterior walls are 12" brick, gypsum lath and plaster on furring.(0.23)

3. Walls exposed in attic (rooms 35 and 37) are 12"

brick, no interior finish.(0.35)

4. Exterior walls in attic (rooms 36,38,39) are asphalt siding exterior with a gypsum board interior. (0.42)

B. Ceilings are gypsum board.(0.65)

C. Roof is asphalt shingles, building paper on wood sheathing.(0.40)

D. Basement floor is concrete.(2 Btu/hr-ft^2)

E. Basement wall below grade is brick.(4 Btu/hr-ft^2)

F. Glass is single thickness, vertical sheets.(1.02)

G. Doors are wooden.(0.36)

H. Infiltration is based on 15 mph wind, double hung wooden sash windows, non-weatherstripped.(39cfh per crack foot)

I. Ceiling heights are:

1. Basement 7'-3"
2. First floor 10'-2"
3. Second floor 10'-2"
4. Attic 10'-2" (irregular)

Rm	Part of Building	Net Area	Coefficient	Temp. Diff.	Heat Loss	Total Heat Loss
Basement						
1	Wall	109.2	0.23	80	2,010	
	Glass	9.0	1.02	80	734	
	Door	22.8	0.36	80	656	
	Floor	394.0	2.0		788	
	Wall (B.G.)	150.0	4.0		600	

Rm	Part of Building	Net Area	Coefficient	Temp. Diff.	Heat Loss	Total Heat Loss
	Infiltration			80	2,140	6,928
2	Wall	43.5	0.23	80	801	
	Glass	9.0	1.02	80	735	
	Floor	299.0	2.0		598	
	Wall (B.G.)	56.3	4.0		225	
	Infiltration			80	1,010	3,369
3	Wall	119.5	0.23	80	2,200	
	Glass	9.0	1.02	80	735	
	Floor	333.0	2.0		666	
	Wall (B.G.)	137.5	4.0		550	
	Infiltration			80	1,010	5,984
4	Wall	92.2	0.23	80	1,695	
	Glass	7.6	1.02	80	621	
	Floor	187.0	2.0		374	
	Wall (B.G.)	107.0	4.0		428	
	Infiltration			80	955	4,073
5	Wall	240.8	0.23	80	4,440	
	Glass	15.2	1.02	80	1,240	
	Floor	641.0	2.0		1,282	
	Wall (B.G.)	274.0	4.0		1,096	
	Infiltration			80	1,910	9,960
6	Floor	67.5	2.0		135	135

Rm	Part of Building	Net Area	Coefficient	Temp. Diff.	Heat Loss	Total Heat Loss
First Floor						
7	Wall	229.5	0.23	80	4,220	
	Glass	45.0	1.02	80	3,670	
	Door	17.5	0.36	80	505	
	Infiltration			80	2,195	10,590
8	Wall	229.5	0.23	80	940	
	Glass	45.0	1.02	80	1,223	
	Infiltration			80	1,097	3,260
9	Wall	202.0	0.23	80	3,715	
	Glass	48.0	1.02	80	3,920	
	Infiltration			80	3,380	13,178
10	Wall	277.5	0.23	80	5,110	
	Glass	45.0	1.02	80	3,670	
	Door	38.5	0.36	80	1,110	
	Infiltration				3,965	13,855
11	Wall	154.5	0.23	80	2,845	
	Glass	15.0	1.02	80	1,223	
	Infiltration			80	1,125	5,183
12	Wall	31.7	0.23	80	583	
	Door	17.5	1.02	80	505	
	Infiltration			80	1,125	2,213
13	Wall	19.8	0.23	80	364	
	Glass	9.0	1.02	80	735	
	Infiltration			80	937	2,036
14	Wall	12.7	0.23	80	2,340	

Rm	Part of Building	Net Area	Coefficient	Temp. Diff.	Heat Loss	Total Heat Loss
	Glass	45.0	1.02	80	3,670	
	Infiltration			80	2,195	8,105
15	Wall	273.0	0.23	80	5,020	
	Glass	63.0	1.02	80	5,140	
	Infiltration			80	3,370	13,530
16	Wall	61.0	0.23	80	1,122	
	Glass	15.0	1.02	80	1,224	
	Infiltration			80	1,095	3,441
Second Floor						
18	Wall	242.0	0.23	80	5,340	
18a	Glass	48.0	1.02	80	3,920	
	Infiltration			80	1,910	11,150
19	Wall	55.0	0.23	80	1,012	
	Glass	16.0	1.02	80	1,305	
	Infiltration			80	1,108	3,425
20	Wall	204.0	0.23	80	4,510	
25	Glass	41.0	1.02	80	3,340	
26	Infiltration			80	2,540	10,390
21	Wall	109.5	0.23	80	2,515	
	Glass	16.0	1.02	80	1,305	
	Infiltration			80	1,108	4,928
22	Wall	118.2	0.23	80	2,180	
	Glass	17.8	1.02	80	1,451	
	Infiltration			80	1,174	4,805
23	Wall	54.0	0.23	80	1,288	

Rm	Part of Building	Net Area	Coefficient	Temp. Diff.	Heat Loss	Total Heat Loss
	Glass	16.0	1.02	80	1,305	
	Infiltration			80	1,108	3,701
28	Wall	131.0	0.23	80	2,720	
	Glass	16.0	1.02	80	1,305	
	Infiltration			80	1,108	5,133
29	Wall	106.0	0.23	80	1,950	
	Glass	16.0	1.02	80	1,305	
	Infiltration			80	1,108	4,363
30	Wall	141.2	0.23	80	2,600	
	Glass	33.8	1.02	80	2,760	
	Infiltration			80	1,174	6,534
31	Wall	414.2	0.23	80	7,610	
32	Glass	33.8	1.02	80	2,760	
33	Infiltration			80	1,174	11,544
Third Floor (Attic)						
35	Wall	81.0	0.35	80	2,270	
	Glass	32.5	1.02	80	2,655	
	Ceiling	528.0	0.65	38.7	13,300	
	Infiltration			80	1,652	19,177
36	East Wall	176.0	0.42	80	5,920	
	North Wall	117.0	0.35	80	3,275	
	Glass	23.0	1.02	80	1,880	
	Ceiling	281.0	0.65	38.7	7,060	
	Infiltration			80	982	19,177

Rm	Part of Building	Net Area	Coefficient	Temp. Diff.	Heat Loss	Total Heat Loss
37	Wall	36.9	0.35	80	1,005	
	Glass	12.0	1.02	80	978	
	Ceiling	338.0	0.65	38.7	8,500	
	Infiltration			80	982	11,465
38	Wall	324.0	0.42	80	10,900	
	Glass	50.0	1.02	80	4,070	
	Ceiling	600.0	0.65	38.7	15,100	
	Infiltration			80	2,740	32,810
39	Wall	85.5	0.42	80	288	
	Glass	9.5	1.02	80	775	
	Ceiling	321.0	0.65	38.7	13,120	
	Infiltration			80	1,038	15,221
					TOTAL	270,285

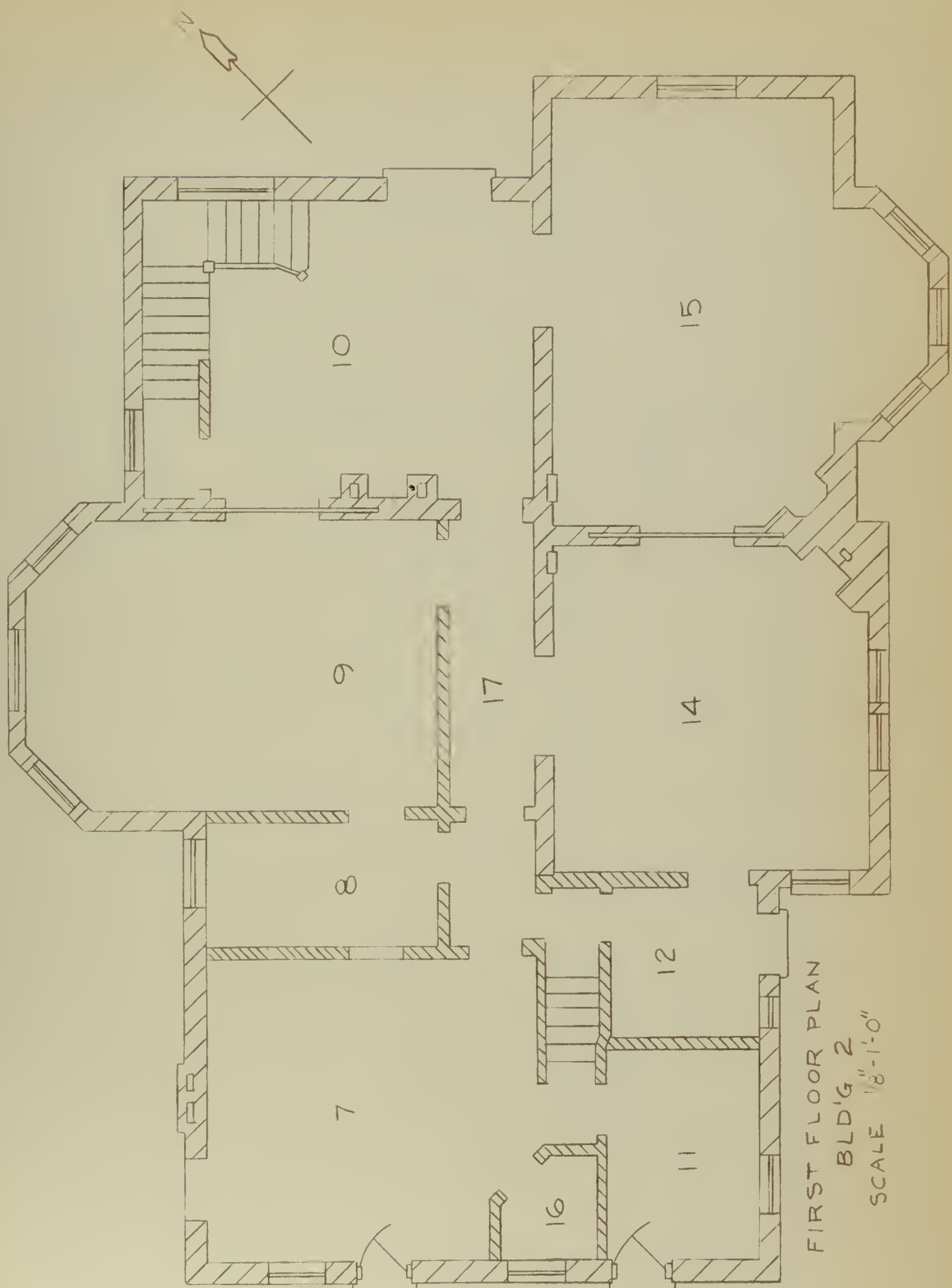
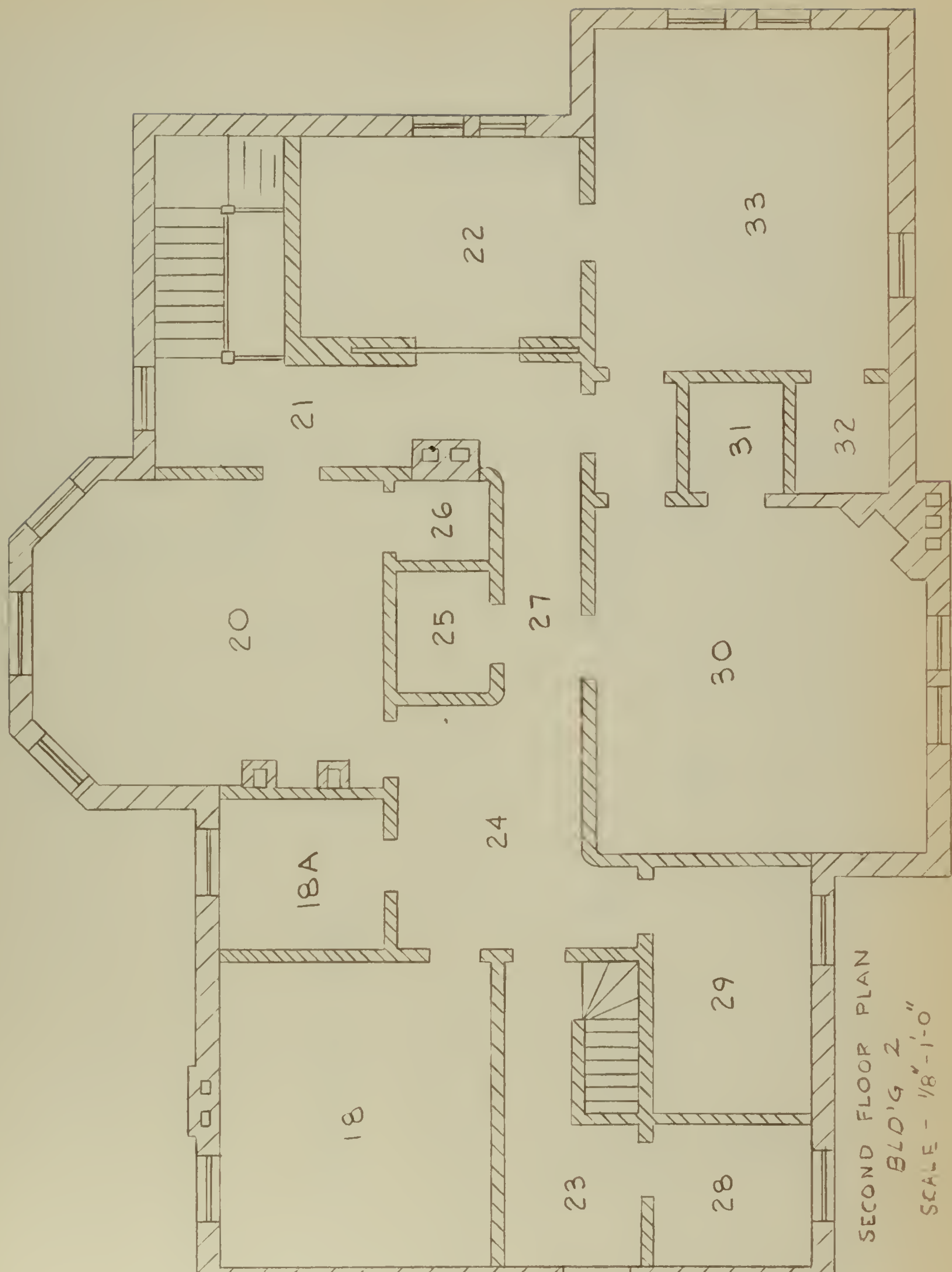


FIGURE 1


SECOND FLOOR PLAN
BLD'G 2
SCALE - 1/8" - 1'-0"
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18A
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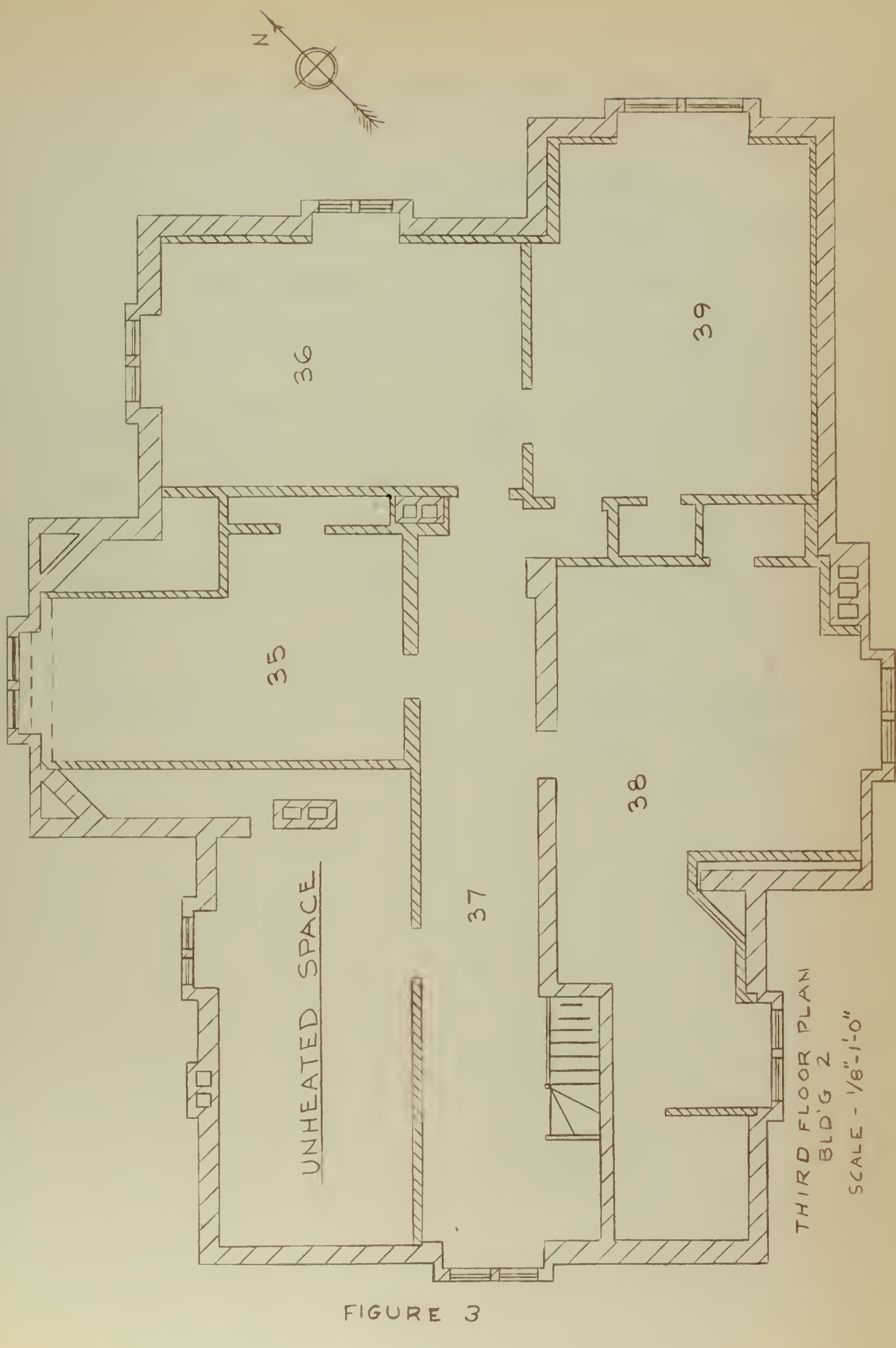
FIGURE 2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UNHEATED SPACE
THIRD FLOOR PLAN
BLD'G 2
SCALE - 1/8"-1'-0"

FIGURE 3

III. Design heat loss for Building 12

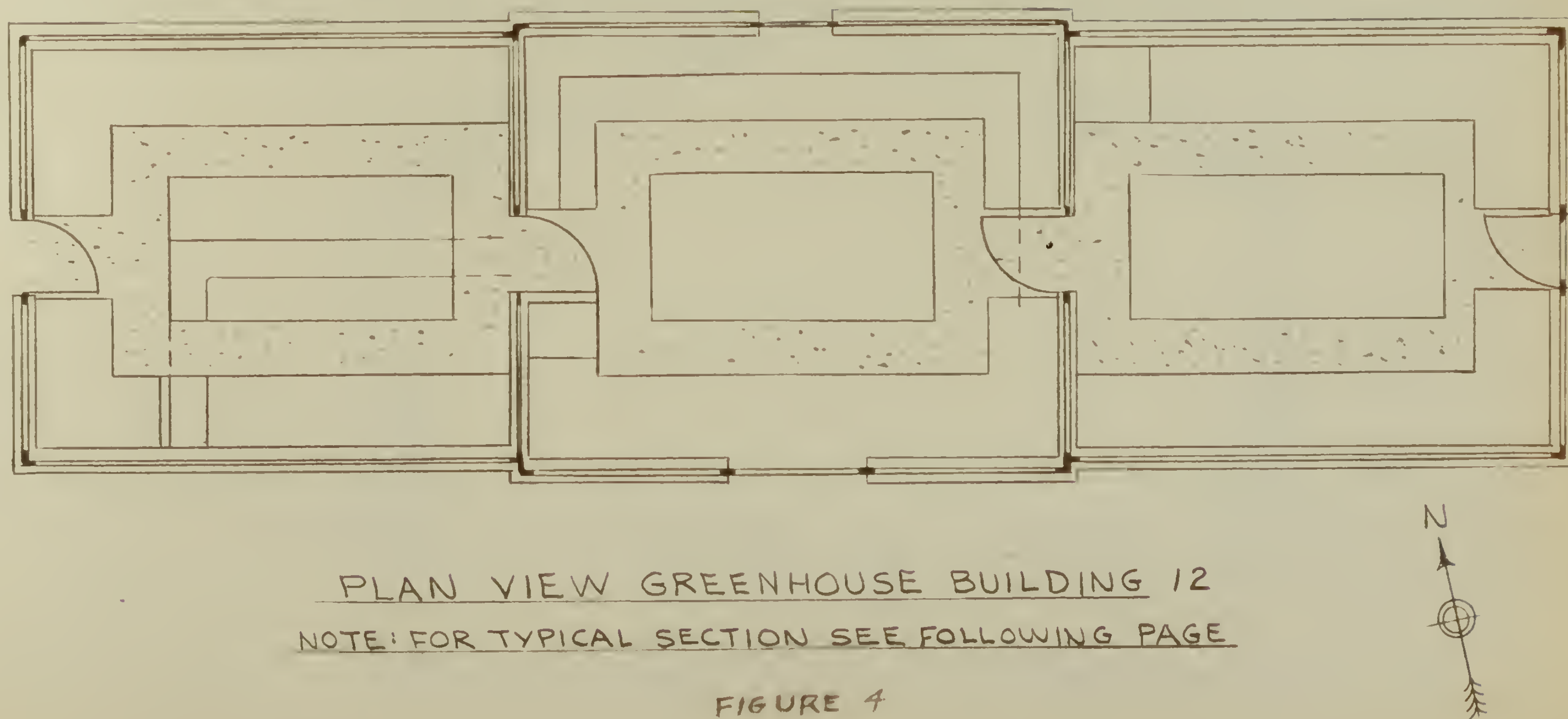
A. Walls are brick veneer on stone with no interior finish.(0.516)

B. Glass is single vertical sheets.(1.02)

C. Floor is dirt. Conductivity is approximately 8 Btu/hr-ft. (assume average heat loss of 4 Btu/hr-ft^2)

D. Infiltration loss is based on two air changes per hour.

Rm	Part of Building	Net Area	Coefficient	Temp. Diff.	Heat Loss	Total Heat Loss
1	Wall	399	0.516	80	16,450	
	Glass	766	1.02	80	62,500	
	Roof (Glass)	1,458	1.02	80	119,000	
	Floor	1,120	4.0		4,480	
	Infiltration				29,400	231,830
					TOTAL	231,830



PLAN VIEW GREENHOUSE BUILDING 12

NOTE: FOR TYPICAL SECTION SEE FOLLOWING PAGE

FIGURE 4

SCALE: $\frac{1}{8}'' = 1'-0''$

IV. Design heat loss for Building 10

A. Walls are as follows:

1. Basement walls are 24" concrete.(0.11)

2. Exterior walls consist of a 4" brickface on an 8" hollow clay block with a plaster interior finish. (0.23)

B. Ceilings are celotex on furring, with wood or concrete floors.(0.23 and 0.16)

C. Roof is flat concrete (5 ply built up 0.16) or wooden pitched roof covered with slate.(0.23)

D. Doors are wooden (0.36) or glass with metal sash.(1.02)

E. Glass is single thickness, vertical sheets.(1.02)

F. Basement floor is concrete.(2 Btu/hr-ft^2)

G. Basement walls below grade are 12" concrete.(4 Btu/hr-ft^2)

H. Infiltration is based on 15 mph wind velocity with 88 cfh per crack foot. The windows are double hung with metal sash.

I. Ceiling heights are:

1. Basement 8'-2"

2. First floor 10'-10"

3. Second floor 10'-11"

4. Third floor 10'-10"

Rm	Part of Building	Net Area	Coefficient	Temp. Diff.	Heat Loss	Total Heat Loss
Basement						
1	Wall	79	0.11	80	695	

Rm	Part of Building	Net Area	Coefficient	Temp. Diff.	Heat Loss	Total Heat Loss
	Wall (B.G.)	57	2.0		104	
	Interior Wall	19	1.0	14	19	
	Interior Glass	9	1.02	14	128	
	Interior Wall (B.G.)	29	2.0		58	
	Floor	116	2.0		233	1,237
2	Interior Wall	19	0.11	14	29	
	Interior Glass	9	1.02	14	128	
	Interior Wall (B.G.)	29	1.0		29	
	Floor	116	2.0		233	419
3	Interior Wall	138	0.11	14	212	
	Interior Glass	18	1.02	14	257	
	Interior Wall (B.G.)	163	1.0		163	
	Floor	741	2.0		1,480	2,114
4	Wall	29	0.11	80	255	
	Wall (B.G.)	30	4.0		60	
	Interior Wall	41	0.11	14	63	
	Interior Glass	18	1.02	14	257	
	Interior Wall (B.G.)	62	1.0		124	

Rm	Part of Building	Net Area	Coefficient	Temp. Diff.	Heat Loss	Total Heat Loss
	Floor	138	2.0		2,777	3,536
5	Floor	102	2.0		203	203
6	Floor	76	2.0		152	152
7	Wall	22	0.11	80	194	
	Door	21	0.36	80	605	
	Floor	531	2.0		1,062	
	Wall (B.G.)	56	2.0		102	2,963
8	Wall	106	0.11	80	932	
	Glass	9	1.02	80	730	
	Floor	199	2.0		397	
	Wall (B.G.)	120	2.0		240	
	Infiltration			80	1,648	3,947
9	Wall	54	0.11	80	475	
	Glass	18	1.02	80	1,470	
	Floor	336	2.0		672	
	Wall (B.G.)	75	2.0		150	
	Infiltration			80	3,295	6,062
10	Wall	31	0.11	80	272	
	Floor	143	2.0		286	
	Wall (B.G.)	32	2.0		64	622
11	Wall	39	0.11	80	343	
	Glass	18	1.02	80	1,470	
	Floor	268	2.0		536	

Rm	Part of Building	Net Area	Coefficient	Temp. Diff.	Heat Loss	Total Heat Loss
	Wall (B.G.)	60	2.0		120	
	Infiltration			80	3,295	5,764
12	Wall	51	0.11	80	449	
	Glass	9	1.02	80	730	
	Floor	280	2.0		560	
	Wall (B.G.)	62	2.0		124	
	Infiltration			80	1,648	3,511
13	Wall	51	0.11	80	449	
	Floor	293	2.0		587	
	Wall (B.G.)	61	2.0		122	
	Interior Wall	51	0.11	14	79	
	Interior Wall (B.G.)	61	2.0		122	1,359
14,15, and 16 are unheated spaces.						
17	Wall	106	0.11	80	932	
	Glass	18	1.02	80	1,430	
	Floor	589	2.0		1,178	
	Wall (B.G.)	119	2.0		238	
	Interior Wall	65	0.11	14	100	
	Interior Wall (B.G.)	159	2.0		318	
	Infiltration			80	4,308	8,504
18	Wall	386	0.11	80	3,400	

Rm	Part of Building	Net Area	Coefficient	Temp. Diff.	Heat Loss	Total Heat Loss
	Glass	144	1.02	80	6,450	
	Door	79	1.02	80		
	Floor	3,550	2.0		7,100	
	Wall (B.G.)	527	2.0		1,054	
	Infiltration			80	13,200	31,204
19	Wall (18")	48	0.14	80	538	
	Glass	18	1.02	80	1,430	
	Floor	198	2.0		396	
	Wall (B.G.)	69	2.0		138	
	Infiltration			80	3,295	5,797
20	Floor	396	2.0		792	792
21	Floor	372	2.0		744	744
22	Wall	44	0.14	80	493	
	Glass	9	1.02	80	730	
	Door	64	0.36	80	1,845	
	Floor	271	2.0		542	
	Wall (B.G.)	53	2.0		106	
	Infiltration			80	6,720	10,436
23	Wall	311	0.14	80	3,480	
	Glass	105	1.02	80	8,580	
	Floor	272	2.0		544	
	Wall (B.G.)	435	2.0		870	
	Infiltration			80	9,880	23,354

Rm	Part of Building	Net Area	Coefficient	Temp. Diff.	Heat Loss	Total Heat Loss
24	Wall	182	0.14	80	2,040	
	Glass	6	1.02	80	490	
	Floor	510	2.0		1,020	
	Wall (B.G.)	196	2.0		392	
	Infiltration			80	1,648	5,690
25	Wall	29	0.14	80	325	
	Glass	9	1.02	80	730	
	Floor	130	2.0		260	
	Wall (B.G.)	40	2.0		80	
	Infiltration			80	1,142	2,537
First Floor						
1	Wall	67	0.23	80	1,230	
	Glass	26	1.02	80	2,125	
	Infiltration			80	2,400	5,755
2	Wall	51	0.23	80	938	
	Glass	26	1.02	80	2,125	
	Infiltration			80	2,400	5,463
4	Wall	53	0.23	80	975	
	Glass	26	1.02	80	2,125	
	Infiltration			80	2,500	5,600
6	Glass	157	1.02	80	12,820	
	Door	52	1.02	80	4,250	
	Infiltration			80	5,200	22,270
7	Wall	228	0.23	80	4,190	

Rm	Part of Building	Net Area	Coefficient	Temp. Diff.	Heat Loss	Total Heat Loss
	Glass	78	1.02	80	6,360	
	Infiltration			80	5,000	15,550
8	Wall	142	0.23	80	2,615	
	Glass	52	1.02	80	4,250	
	Infiltration			80	5,000	11,875
9	Wall	107	0.23	80	1,970	
	Glass	52	1.02	80	4,250	
	Infiltration			80	5,000	11,220
10	Wall	138	0.23	80	2,540	
	Glass	26	1.02	80	2,125	
	Infiltration			80	4,665	7,165
11	Wall	132	0.23	80	2,430	
	Glass	52	1.02	80	4,250	
	Floor	314	0.13	14	571	
	Infiltration			80	5,000	12,251
12	Wall	174	0.23	80	3,200	
	Glass	52	1.02	80	4,250	
	Floor	386	0.13	14	703	
	Infiltration			80	5,000	13,153
13	Wall	332	0.23	80	6,110	
	Glass	130	1.02	80	10,620	
	Floor	386	0.13	14	703	
	Infiltration			80	7,500	24,993
14	Wall	171	0.23	80	3,145	
	Glass	78	1.02	80	6,360	

Rm	Part of Building	Net Area	Coefficient	Temp. Diff.	Heat Loss	Total Heat Loss
	Floor	396	0.13	14	721	
	Infiltration			80	7,500	17,726
15	Wall	171	0.23	80	3,660	
	Glass	104	1.02	80	8,570	
	Floor	356	0.13	14	644	
	Infiltration			80	5,000	17,874
16	Wall	199	0.23	80	3,660	
	Glass	104	1.02	80	8,570	
	Floor	356	0.13	14	644	
	Infiltration			80	3,300	8,097
17	Wall	405	0.23	80	7,450	
	Glass	130	1.02	80	10,620	
	Door	26	1.02	80	2,150	
	Floor	2,280	0.13	14	23,750	
	Infiltration			80	14,700	58,670
18	Wall	270	0.23	80	4,970	
	Glass	26	1.02	80	2,150	
	Door	26	1.02	80	2,150	
	Floor	163	0.13	14	297	
	Infiltration			80	4,700	14,367
19	Wall	120	0.23	80	2,210	
	Glass	52	1.02	80	4,250	
	Floor	319	0.13	14	581	
	Infiltration			80	5,000	11,941
20	Wall	100	0.23	80	1,840	

Rm	Part of Building	Net Area	Coefficient	Temp. Diff.	Heat Loss	Total Heat Loss
	Glass	52	1.02	80	4,250	
	Floor	282	0.13	14	514	
	Infiltration			80	5,000	11,604
21	Wall	100	0.23	80	1,840	
	Glass	52	1.02	80	4,250	
	Floor	282	0.13	14	514	
	Infiltration			80	5,000	11,604
22	Wall	113	0.23	80	2,080	
	Glass	26	1.02	80	2,125	
	Floor	268	0.13	14	488	
	Infiltration			80	2,500	7,193
23	Wall	90	0.23	80	1,657	
	Glass	52	1.02	80	4,250	
	Floor	272	0.13	14	495	
	Infiltration			80	5,000	11,402
24	Wall	173	0.23	80	3,180	
	Glass	78	1.02	80	6,360	
	Floor	126	0.13	14	230	
	Infiltration			80	5,000	14,770
25	Wall	447	0.23	80	8,240	
	Glass	208	1.02	80	17,000	
	Floor	1,470	0.13	14	2,680	
	Infiltration			80	20,000	47,920
26	Floor	568	0.13	14	1,035	1,035
27	Wall	62	0.23	80	1,140	

Rm	Part of Building	Net Area	Coefficient	Temp. Diff.	Heat Loss	Total Heat Loss
	Glass	26	1.02	80	2,120	
	Infiltration			80	2,500	5,765
28	Wall	75	0.23	80	1,380	
	Glass	26	1.02	80	2,125	
	Infiltration			80	5,000	8,505
29	Wall	107	0.23	80	1,970	
	Door	26	1.02	80	2,125	
	Infiltration			80	2,200	6,295
31	Wall	140	0.23	80	2,575	
	Glass	26	1.02	80	2,125	
	Infiltration			80	2,500	7,200
32	Wall	777	0.23	80	14,300	
	Glass	264	1.02	80	21,450	
	Door	52	1.02	80	4,250	
	Infiltration			80	2,200	42,200
33	Wall	116	0.23	80	2,135	
	Glass	52	1.02	80	4,250	
	Infiltration			80	5,000	11,385
34	Wall	82	0.23	80	1,508	
	Glass	52	1.02	80	4,250	
	Infiltration			80	5,000	10,758
35	Wall	104	0.23	80	1,915	
	Glass	26	1.02	80	4,250	
	Infiltration			80	2,500	8,665
36	Wall	199	0.23	80	3,660	

Rm	Part of Building	Net Area	Coefficient	Temp. Diff.	Heat Loss	Total Heat Loss
	Glass	78	1.02	80	6,360	
	Infiltration			80	7,500	17,520
37	Wall	279	0.23	80	5,140	
	Glass	104	1.02	80	8,500	
	Infiltration			80	5,000	18,640
38	Wall	820	0.23	80	15,100	
	Glass	286	1.02	80	23,400	
	Door	26	1.02	80	2,150	
	Infiltration			80	15,000	55,650
39	Wall	136	0.23	80	2,500	
	Glass	26	1.02	80	2,150	
	Door	26	1.02	80	2,150	
	Infiltration			80	4,700	11,500
Second Floor						
1	Wall	51	0.23	80	938	
	Glass	26	1.02	80	2,150	
	Infiltration			80	2,500	5,588
2	Wall	66	0.23	80	1,214	
	Glass	26	1.02	80	2,150	
	Infiltration			80	2,500	5,864
4	Wall	76	0.23	80	920	
	Door	26	0.36	80	748	
	Infiltration			80	2,200	3,868
5	Wall	104	0.23	80	1,912	
	Glass	26	1.02	80	2,150	

Rm	Part of Building	Net Area	Coefficient	Temp. Diff.	Heat Loss	Total Heat Loss
	Infiltration			80	2,500	6,562
6	Wall	217	0.23	80	3,950	
	Glass	78	1.02	80	6,360	
	Infiltration			80	5,000	15,310
7	Wall	328	0.23	80	6,040	
	Glass	130	1.02	80	10,620	
	Infiltration			80	12,500	29,160
8	Wall	192	0.23	80	3,530	
	Glass	52	1.02	80	4,250	
	Infiltration			80	2,500	10,280
10	Wall	127	0.23	80	2,340	
	Glass	52	1.02	80	4,250	
	Ceiling	305	0.23	65	561	
	Infiltration			80	5,000	12,151
11	Wall	77	0.23	80	1,416	
	Glass	26	1.02	80	2,150	
	Ceiling	176	0.23	65	324	
	Infiltration			80	2,500	6,390
12	Wall	94	0.23	80	1,732	
	Glass	52	1.02	80	4,250	
	Ceiling	250	0.23	65	460	
	Infiltration			80	5,000	11,442
13	Wall	73	0.23	80	1,345	
	Glass	26	1.02	80	2,150	
	Ceiling	169	0.23	65	312	

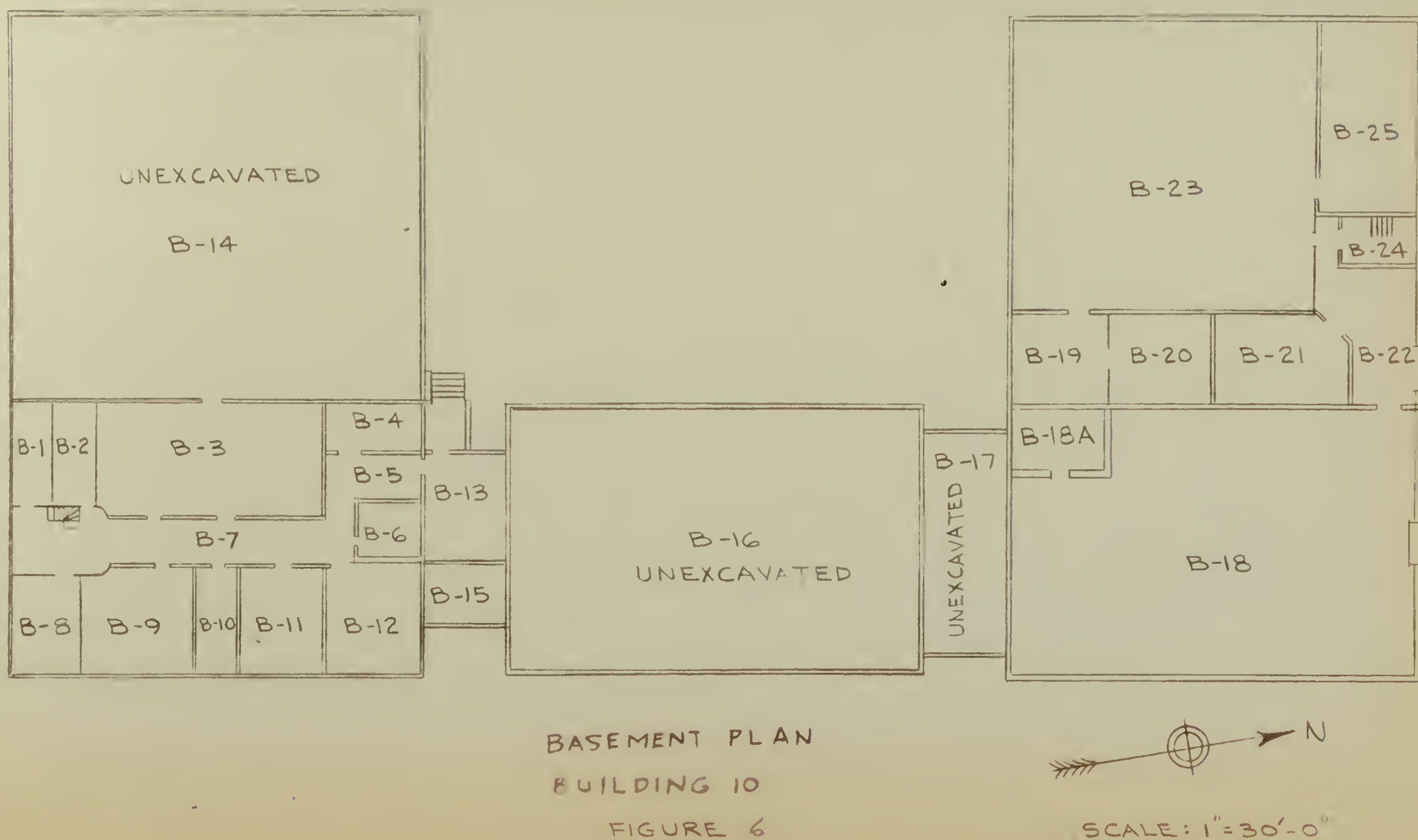
Rm	Part of Building	Net Area	Coefficient	Temp. Diff.	Heat Loss	Total Heat Loss
	Infiltration			80	2,500	6,307
14	Wall	77	0.23	80	1,416	
	Glass	104	1.02	80	8,500	
	Ceiling	312	0.23	65	574	
	Infiltration			80	5,000	15,490
15	Wall	801	0.23	80	14,730	
	Glass	338	1.02	80	27,600	
	Door	26	0.36	80	2,150	
	Ceiling	2,835	0.23	65	5,000	
	Infiltration			80	22,200	71,680
16	Wall	139	0.23	80	2,553	
	Glass	52	1.02	80	4,250	
	Infiltration			80	5,000	11,793
17	Wall	124	0.23	80	2,277	
	Glass	52	1.02	80	4,250	
	Infiltration			80	5,000	11,527
18	Wall	201	0.23	80	3,705	
	Glass	78	1.02	80	6,360	
	Infiltration			80	5,000	15,065
19	Wall	664	0.23	80	12,210	
	Glass	475	1.02	80	38,785	
	Infiltration			80	25,000	75,995
20	Wall	61	0.23	80	1,122	
	Glass	26	1.02	80	2,125	
	Infiltration			80	2,500	5,747

Rm	Part of Building	Net Area	Coefficient	Temp. Diff.	Heat Loss	Total Heat Loss
21	Wall	34	0.23	80	626	
	Glass	26	1.02	80	2,125	
	Infiltration			80	2,500	5,251
22	Wall	112	0.23	80	2,026	
	Glass	52	1.02	80	4,250	
	Infiltration			80	5,000	11,310
23	Wall	137	0.23	80	2,520	
	Glass	26	1.02	80	4,125	
	Infiltration			80	2,500	9,145
25	Wall	1,008	0.23	80	18,550	
	Glass	277	1.02	80	22,552	
	Door	26	0.36	80	748	
	Infiltration			80	15,000	56,950
26	Wall	83	0.23	80	1,529	
	Glass	52	1.02	80	4,250	
	Infiltration			80	5,417	11,196
27	Wall	100	0.23	80	1,840	
	Glass	26	1.02	80	2,125	
	Infiltration			80	2,890	6,855
28	Wall	200	0.23	80	3,680	
	Glass	78	1.02	80	6,360	
	Infiltration			80	8,355	18,395
29	Wall	277	0.23	80	5,090	
	Glass	111	1.02	80	9,066	
	Infiltration			80	5,000	19,156

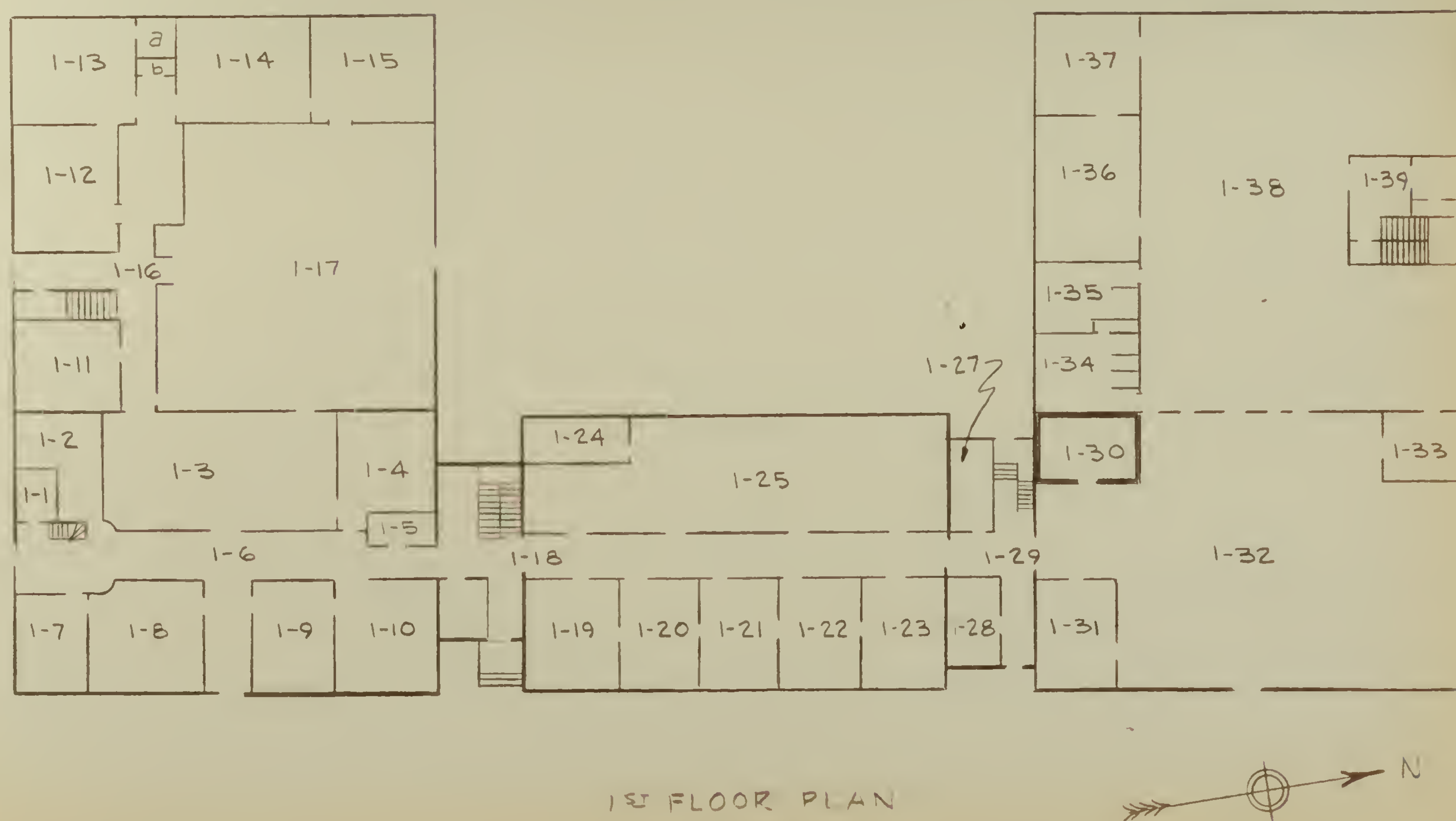
Rm	Part of Building	Net Area	Coefficient	Temp. Diff.	Heat Loss	Total Heat Loss
30	Wall	284	0.23	80	5,220	
	Glass	124	1.02	80	10,162	
	Door	26	0.36	80	748	
	Infiltration			80	9,700	25,830
31	Wall	260	0.23	80	4,780	
	Glass	167	1.02	80	9,016	
	Infiltration			80	5,000	18,796
32	Wall	180	0.23	80	3,311	
	Glass	52	1.02	80	4,250	
	Infiltration			80	5,000	12,561
33	Wall	91	0.23	80	1,666	
	Glass	26	1.02	80	2,125	
	Infiltration			80	2,500	6,291
34	Wall	182	0.23	80	2,345	
	Glass	87	1.02	80	7,160	
	Infiltration			80	7,500	17,005
Third Floor						
1	Wall	182	0.23	80	3,345	
	Glass	78	1.02	80	6,360	
	Ceiling	128	0.16	75	1,538	
	Infiltration			80	5,000	16,243
2	Wall	250	0.23	80	4,600	
	Glass	78	1.02	80	6,360	
	Ceiling	222	0.16	75	2,540	
	Infiltration			80	5,000	18,500

Rm	Part of Building	Net Area	Coefficient	Temp. Diff.	Heat Loss	Total Heat Loss
3	Wall	986	0.23	80	18,150	
	Glass	338	1.02	80	27,600	
	Door	26	0.36	80	750	
	Ceiling	2,582	0.16	75	31,000	
	Infiltration			80	16,400	93,900
4	Ceiling	60	0.16	75	720	720
5	Wall	125	0.23	80	2,300	
	Glass	52	1.02	80	4,250	
	Ceiling	374	0.16	75	4,480	
	Infiltration			80	2,500	13,530
6	Wall	265	0.23	80	4,870	
	Glass	78	1.02	80	6,360	
	Ceiling	250	0.16	75	3,000	
	Infiltration			80	5,000	19,230
7	Wall	240	0.23	80	4,420	
	Glass	52	1.02	80	4,250	
	Ceiling	180	0.16	75	2,160	
	Infiltration			80	5,000	15,830
8	Wall	190	0.23	80	3,495	
	Glass	78	1.02	80	6,360	
	Ceiling	135	0.16	75	1,620	
	Infiltration			80	5,000	16,478
9	Wall	152	0.23	80	2,795	
	Glass	52	1.02	80	4,250	
	Ceiling	313	0.16	75	3,760	

Rm	Part of Building	Net Area	Coefficient	Temp. Diff.	Heat Loss	Total Heat Loss
	Infiltration			80	2,500	13,305
10	Wall	310	0.23	80	5,700	
	Glass	52	1.02	80	4,250	
	Ceiling	138	0.16	75	1,658	
	Infiltration			80	5,000	16,608
11	Wall	163	0.23	80	2,995	
	Ceiling	132	0.16	75	1,590	4,585
12	Wall	1,377	0.23	80	25,300	
	Glass	468	1.02	80	38,200	
	Door	52	0.36	80	1,500	
	Ceiling	3,493	0.16	75	41,800	
	Infiltration			80	14,700	121,500
					TOTAL	1,576,234

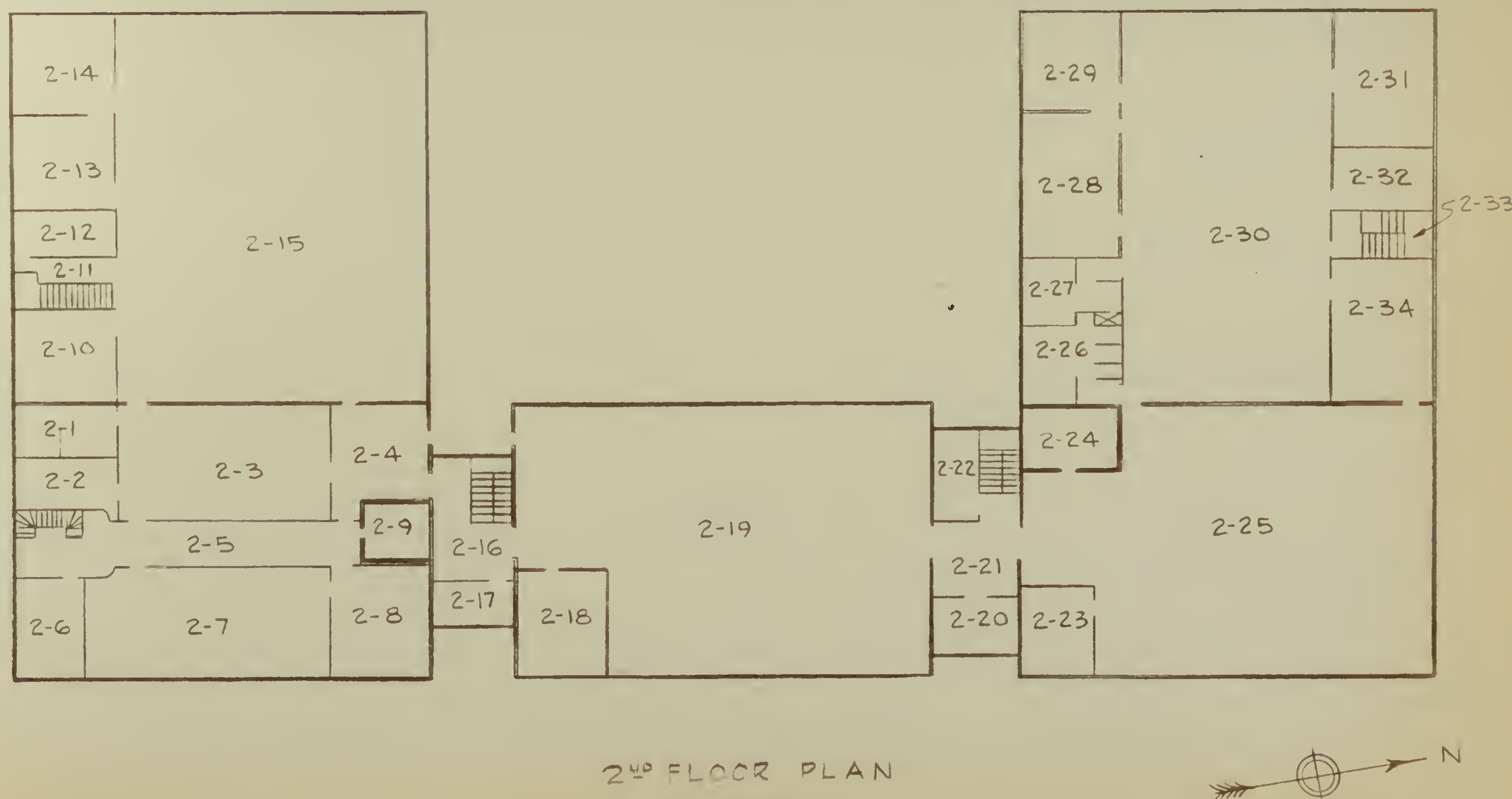


BASEMENT PLAN
BUILDING 10
FIGURE 6



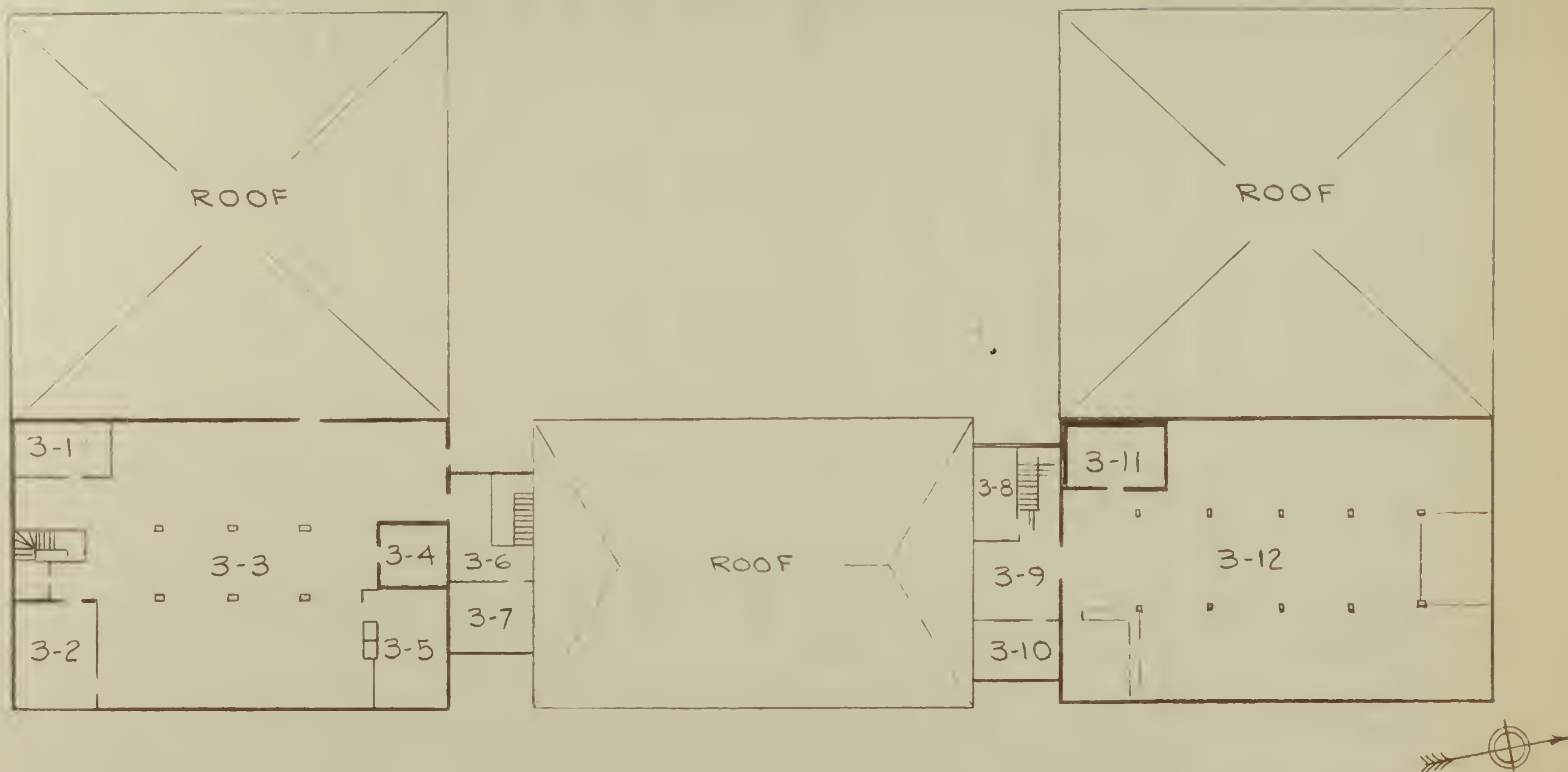
1ST FLOOR PLAN
BUILDING 10
FIGURE 7

SCALE: 1" = 30'0"



2ND FLOOR PLAN
BUILDING 10
FIGURE 8

SCALE: 1" = 30'-0"



3rd FLOOR PLAN
BUILDING 10
FIGURE 9

SCALE 1" = 30'-0"

V. Design heat loss for Building 125

A. Walls are 16" brick. (0.25)

B. Roof is built-up on a 6" gypsum slab. (0.22)

C. Doors are wooden, 40% glass (0.79) and metal roll-up (0.55).

D. Floor is 12" concrete. (2 Btu/hr-ft^2)

E. Infiltration is based on 176 cfh per crack foot.

F. Wall below grade is assumed to transmit 4 Btu/hr-ft^2.

G. Ceiling heights are:

1. Shop area , 27'-4"

2. Other areas 10'-6"

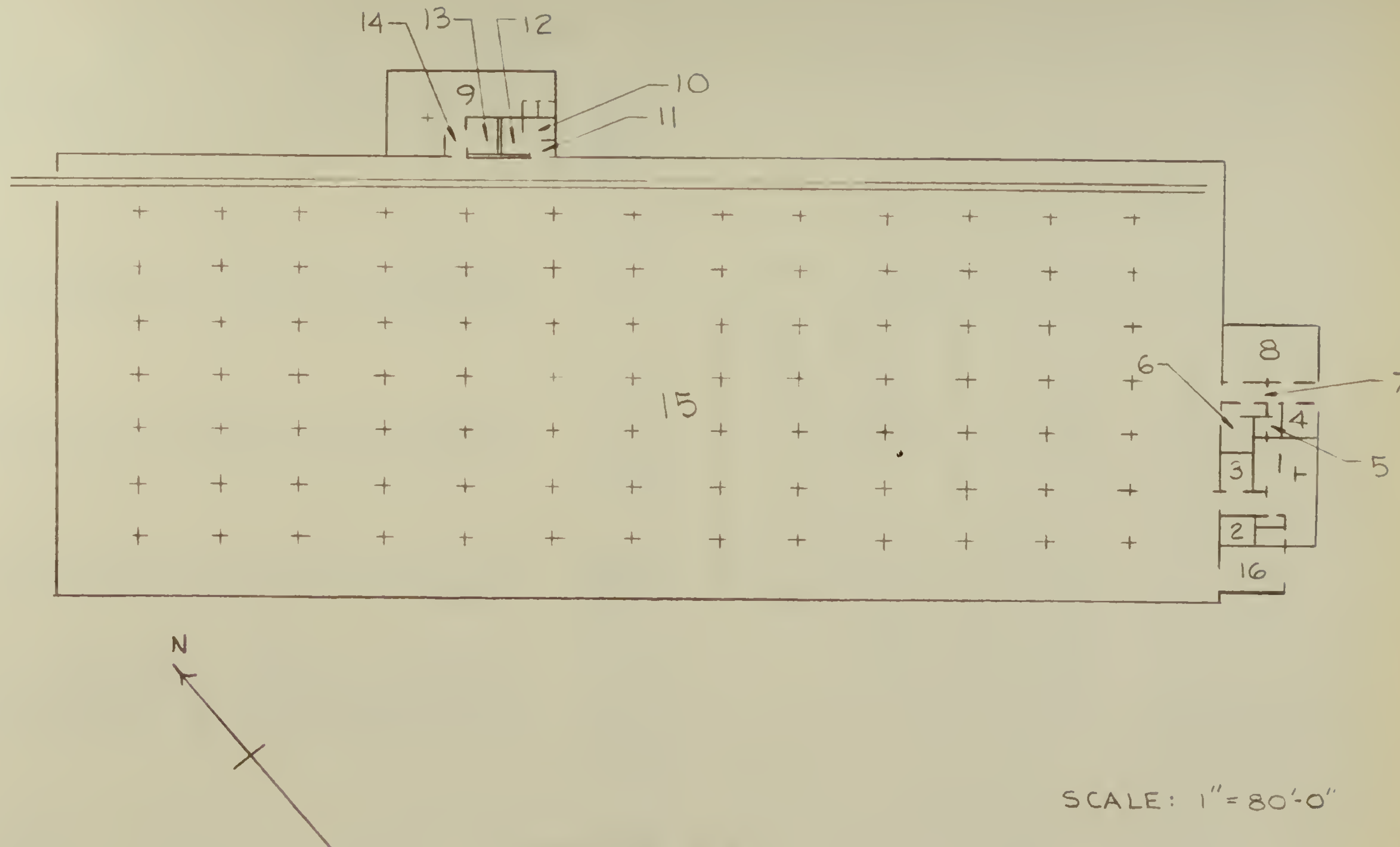
Rm	Part of Building	Net Area	Coefficient	Temp. Diff.	Heat Loss	Total Heat Loss
1	Wall	434	0.25	80	8,680	
	Glass	180	1.02	80	14,670	
	Ceiling	1,014	0.22	80	17,850	
	Floor	1,014	2.0		2,028	
	Infiltration			80	42,444	85,672
2	Ceiling	398	0.22	80	7,010	
	Floor	398	2.0		796	
	Infiltration (Mechanical Ventilator)			80	12,080	19,886
3	Ceiling	396	0.22	80	6,990	
	Floor	396	2.0		793	
	Infiltration (Mechanical Ventilator)			80	12,000	19,783
4	Wall	86	0.25	80	17,260	

Rm	Part of Building	Net Area	Coefficient	Temp. Diff.	Heat Loss	Total Heat Loss
	Glass	45	1.02	80	3,670	
	Ceiling	175	0.22	80	3,080	
	Floor	175	2.0		350	
	Infiltration (Mechanical Ventilator)			80	5,300	29,660
5	Ceiling	96	0.22	80	1,692	
	Floor	96	2.0		192	
	Infiltration (Mechanical Ventilator)			80	2,905	4,789
6	Ceiling	295	0.22	80	5,200	
	Floor	295	2.0		590	
	Infiltration (Mechanical Ventilator)			80	8,940	14,730
7	Wall	27	0.25	80	540	
	Door	68	1.02	80	2,540	
	Ceiling	369	0.22	80	6,500	
	Floor	369	2.0		738	
	Infiltration			80	39,252	49,562
8	Wall	379	0.25	80	7,580	
	Glass	270	1.02	80	22,800	
	Ceiling	965	0.22	80	17,010	
	Floor	965	2.0		1,930	
	Infiltration			80	71,220	91,764
9	Wall	1,128	0.25	80	22,560	
	Glass	252	1.02	80	20,350	
	Ceiling	2,970	0.22	80	52,300	

Rm	Part of Building	Net Area	Coefficient	Temp. Diff.	Heat Loss	Total Heat Loss
	Floor	2,970	2.0		5,940	
	Infiltration			80	34,430	135,580
10	Wall	110	0.25	80	2,200	
	Ceiling	115	0.22	80	2,035	
	Floor	115	2.0		231	
	Infiltration (Mechanical Ventilator)			80	3,495	7,961
11	Wall	53	0.25	80	1,050	
	Ceiling	55	0.22	80	969	
	Floor	55	2.0		110	2,129
12	Ceiling	178	0.22	80	3,140	
	Floor	178	2.0		357	
	Infiltration (Mechanical Ventilator)			80	5,400	8,897
13	Ceiling	168	0.22	80	2,960	
	Floor	168	2.0		336	
	Infiltration (Mechanical Ventilator)			80	5,080	8,376
14	Ceiling	101	0.22	80	1,780	
	Floor	101	2.0		202	
	Infiltration			80	3,055	4,957
15	a. North Wall	5,135	0.27	80	110,900	
	Glass	6,670	1.02	80	545,000	
	Door	140	0.79	80	8,850	
	Wall (B.G.)	2,235	4.0		8,940	673,690

Rm	Part of Building	Net Area	Coefficient	Temp. Diff.	Heat Loss	Total Heat Loss
	b. East Wall	657	0.27	80	14,190	
	Glass	1,930	1.02	80	157,400	
	Door	70	0.79	80	5,710	
	Wall (B.G.)	1,181	4.0		4,724	181,924
	c. South Wall	5,542	0.27	80	119,500	
	Glass	7,300	1.02	80	596,000	
	Door	140	1.02	80	11,420	
	Wall (B.G.)	2,228	4.0		8,912	735,832
	d. West Wall	1,306	0.27	80	28,200	
	Glass	2,650	1.02	80	216,500	
	Door	470	0.55	80	21,100	
	Wall (B.G.)	985	4.0		3,940	269,740
	e. Floor	109,729	2.0		219,458	219,458
	f. Roof Surface	115,372	0.22	80	2,035,000	
	Glass	27,810	1.02	80	2,275,000	4,310,000
	Infiltration			80	6,390,644	6,390,644
16	Wall	446	0.27	80	11,580	
	Door	90	0.55	80	3,960	
	Ceiling	630	0.63	80	3,170	
	Floor	630	2.0		1,260	

Rm	Part of Building	Net Area	Coefficient	Temp. Diff.	Heat Loss	Total Heat Loss
	Infiltration			80	14,220	34,190
					TOTAL	9,537,211



SCALE: 1" = 80'-0"

BUILDING 125
FIGURE 10

VI. Design heat loss for Building 25

A. Walls are 18" reenforced concrete. (0.13)

B. Roof is a built-up on a 6" concrete slab. (0.21)

C. Glass is single sheet vertical. (1.02)

D. Doors are metal roll-up (0.55) and industrial metal (1.02).

E. Floor is concrete. (2 Btu/hr-ft^2)

F. Windows are metal sash with 80% glass. (1.02)

G. Infiltration is based on 176 cfh per crack foot.

H. Ceiling heights, are as follows:

1. First floor 16'-3"

2. Second floor 16'-3"

3. Third floor 16'-3"

Rm	Part of Building	Net Area	Coefficient	Temp. Diff.	Heat Loss	Total Heat Loss
First Floor						
North Wall		1,282	0.13	80	13,320	
	Glass	1,789	1.02	80	145,800	
	Door	184	0.55	80	8,090	167,210
East Wall		1,731	0.13	80	18,000	
	Glass	2,664	1.02	80	217,500	
	Door	160	0.55	80	7,040	242,540
South Wall		1,282	0.13	80	13,320	
	Glass	1,789	1.02	80	145,900	
	Door	184	0.55	80	8,090	167,310
West Wall		1,282	0.13	80	21,150	

Rm	Part of Building	Net Area	Coefficient	Temp. Diff.	Heat Loss	Total Heat Loss
	Glass	4,633	1.02	80	378,000	
	Door	140	0.55	80	11,420	410,570
	Floor	´59,649	2.0		119,298	119,298
	Infiltration			80	994,220	994,220
Second Floor						
North Wall		1,515	0.13	80	15,750	
	Glass	2,011	1.02	80	164,000	179,750
East Wall		1,963	0.13	80	20,400	
	Glass	2,880	1.02	80	235,000	255,400
South Wall		1,515	(same as North Wall)			
	Glass	2,011				179,750
West Wall		2,275	0.13	80	23,600	
	Glass	4,992	1.02	80	407,000	430,600
	Infiltration			80	1,036,004	1,036,004
Third Floor						
North Wall		1,414	0.13	80	14,710	
	Glass	2,112	1.02	80	172,100	186,810
East Wall		2,323	0.13	80	24,150	
	Glass	2,880	1.02	80	235,000	259,150
South Wall		(same as North Wall)				
	Glass					186,810
West Wall		2,635	0.13	80	27,400	
	Glass	4,992	1.02	80	407,000	434,400
	Ceiling	60,749	0.21	80	1,020,000	1,020,000

Rm	Part of Building	Net Area	Coefficient	Temp. Diff.	Heat Loss	Total Heat Loss
	Infiltration			80	1,051,199	1,051,199
					TOTAL	7,320,021

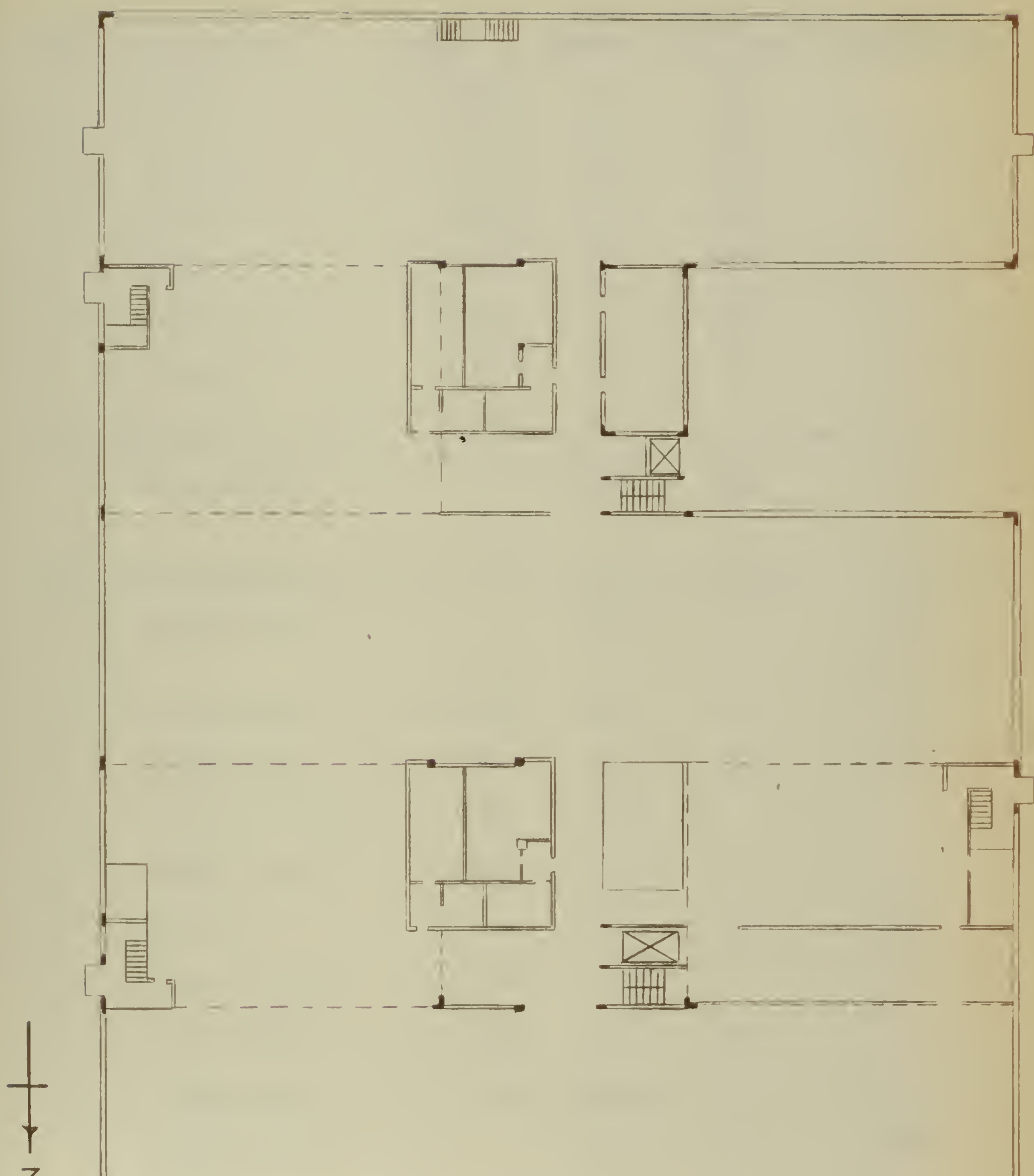


FIGURE 11 FLOOR PLAN
BUILDING 25
SCALE 1"-40' 0"

VII. Summary of load by Building

Bldg.	Description	Volume	Loads (lbs. of steam per hour) Heating	Hot Water	Process Steam
1	Housing	12,560*	398	44	
2	Housing	9,136*	282	41	
3	Housing	9,136*	282	84	
4	Housing	12,351*	390	44	
6	Housing	13,596*	430	94	
8	Housing	10,261*	325	62	
9	Housing	3,705*	117		
	TOTAL GROUP A		2,224	369	0
12	Green House		241	0	0
	TOTAL GROUP B		241	0	0
10	Office Bldg.	601,602	1,640	56	
24	Office Bldg.	83,796	228	21	
41	Recreation Bldg.	40,450	110		
19	Office Space	132,267	360		
21	Cafeteria	204,000	556	145	525
105	Service Office	253,122	790		
108a	Plan. Office	202,390	553	111	
44	Office Bldg.	503,207	1,371		
	TOTAL GROUP C		5,608	333	525
14	Machine Shop	756,289	2,160		

*Indicates heated floor area in lieu of gross volume.

Bldg.	Description	Volume	Loads (lbs. of steam per hour) Heating	Hot Water	Process Steam
17	Maint. Shop	84,746	242	62	
20	Machine Shop	3,444,400	9,840	208	
22	Fire House	110,606	316	29	
30	Carp. Shop	352,353	1,006	21	
35	Machine Shop	5,700,070	15,283	129	
40	Machine Shop	2,786,100	7,959	168	
16	Machine Shop	17,500	50		
101	Oil House	34,084	97		
103	South Bldg.	7,967	23		
104	Steel Shop	124,061	354		
105b	Storehouse	51,846	1,476	59	
110a	Machine Shop	2,925,364	8,357	62	6,937
112	Machine Shop	9,200	26		
114	Machine Shop	61,183	175		104
115	Machine Shop	1,215,285	3,472	115	
120	Office and Shop	43,652	1,382	18	
121	Foundry	112,883	322	21	1,724
123	Wood Shop	107,897	308		8,356
124	Machine Shop	225,120	643		
125	Machine Shop	3,477,648	9,934	221	
	TOTAL GROUP D		63,425	1,113	17,121
38	Storehouse	553,250	1,387		
15	Garage	398,697	925	42	
18	Garage	28,800	67		

Bldg.	Description	Volume	Loads (lbs. of steam per hour) Heating	Hot Water	Process Steam
110b	Unused Shop	5,850,730	13,580		
120a	Unused Shop	967,304	2,245		
122	Wood Shop	19,484	45		735
126	Forge Shop	208,000	483		8,356
130	Machine Shop	388,512	902		
135	Machine Shop	10,741,142	24,931	82	
	TOTAL GROUP D_1		44,565	124	9,091
23	Machine Shop	270,370	678	20	
25	Machine Shop	3,041,282	7,625	10	
T102	Machine Shop	6,138	15	26	
	TOTAL GROUP E		8,318	56	0
136	Boiler House		4,008	2	
	TOTAL GROUP F		4,008	2	0
	Group A		2,224	369	0
	Group B		241	0	0
	Group C		5,608	333	525
	Group D		63,425	1,113	17,121
	Group D_1		44,565	124	9,091
	Group E		8,318	56	0
	Group F		4,008	2	0
	TOTAL		128,389	1,998	26,737

Note: (1) Similar groups indicate similar types of buildings.

(2) 1 pound of steam = 960 Btu.

APPENDIX B

Historical Data for Existing Plant (Alternative 1)

I. Plant design characteristics

A. Operating pressure 150psig

B. Quality of steam 100%

C. Maximum load 300,000 pounds per hr (2 units - 50,000 pounds per hr and 2 units - 100,000 pounds per hr)

D. Fuel oil capacity 500,000 gals of #6 fuel oil

E. City water for make-up is treated with a zeolite process.

F. Control is fully automatic with all units controlled from one central board.

G. Fuel oil is pre-heated and steam is atomized.

H. Feed water is heated and deareated.

II. Plant operating conditions

A. Operating pressure 115psig

B. Quality of steam 100%

C. Peak load 1959 105,500 lbs. per hr

D. See Figures 12 and 13 for typical load curve for each season.

III. Summary of 1959 operation

Table VII Annual Plant Meter Summary

Month	Steam(lbs.)	Oil(gals.)	Raw Water(gals.)
January	51,161,562	415,819	1,332,200
February	44,265,412	362,239	1,129,800

Month	Steam(lb.)	Oil(gals.)	Raw Water(gals.)
March	34,917,069	304,443	1,204,700
April	23,441,164	203,176	857,000
May	9,711,472	88,906	654,400
June	7,199,952	68,160	629,500
July	2,458,150	27,209	242,500
August	5,544,018	58,567	553,100
September	8,624,600	81,424	615,400
October	20,638,844	174,944	850,000
November	32,582,640	264,435	1,231,900
December	40,866,268	333,966	1,437,800
TOTAL	281,411,151	2,383,288	10,738,300

Table VIII Typical Load Curves

	Winter				Spring & Fall		Summer	
Time of Day	Weekday Load	Avg. Temp.	Weekend Load	Avg. Temp.	Weekday Load	Weekend Load	Weekday Load	Weekend Load
000		24.7	61.7	21.4	26.6	20.8	8.1	5.1
0100	65.2	24.2	56.8	20.4	27.8	21.9	8.4	5.5
0200	65.9	22.7	59.1	20.5	28.5	21.2	8.3	5.5
0300	66.6	22.8	58.9	20.1	29.4	20.8	8.3	5.6
0400	66.4	22.0	59.1	19.2	29.8	21.2	8.3	5.6
0500	67.8	22.1	59.6	17.9	29.7	20.8	8.2	5.5
0600	69.5	21.5	59.3	16.9	29.6	21.9	8.3	5.1
0700	70.7	21.1	59.4	16.4	31.7	21.7	9.4	5.4
0800	71.9	22.9	58.9	18.0	30.9	20.8	9.6	5.5
0900	70.8	25.1	57.3	21.1	34.1	22.3	10.5	6.3
1000	68.4	26.9	56.4	22.7	31.6	20.9	10.6	5.7

Time of Day	Winter Weekday Load	Winter Avg. Temp.	Winter Weekend Load	Winter Avg. Temp.	Spring & Fall Weekday Load	Spring & Fall Weekend Load	Summer Weekday Load	Summer Weekend Load
1100	65.4	28.6	55.1	25.3	31.1	21.2	9.6	5.8
12 N.	63.3	30.3	55.0	27.3	29.5	20.5	10.4	5.5
1300	62.7	32.2	53.2	28.9	29.0	20.4	9.9	4.6
1400	60.1	32.4	52.9	29.4	28.6	19.8	10.4	5.7
1500	59.9	31.8	52.8	30.6	26.9	20.3	9.8	5.1
1600	59.1	32.1	52.7	30.6	27.2	19.4	9.1	5.1
1700	59.6	30.8	55.0	29.3	30.5	23.7	8.6	5.3
1800	59.2	29.4	56.4	27.4	28.2	21.0	8.6	5.0
1900	60.5	27.9	57.4	27.1	25.7	22.5	8.6	5.2
2000	60.0	25.7	58.2	25.9	28.0	21.7	8.3	5.4
2100	61.5	25.5	60.7	25.0	27.2	22.1	8.6	5.0
2200	62.1	25.1	60.5	23.3	27.7	23.8	8.3	5.6
2300	62.1	24.8	61.3	23.2	28.9	22.7	8.2	5.6
2400	65.2	24.7	61.7	21.4	26.6	20.8	8.1	5.1

Note: (1) Loads are shown in lbs. of steam per hr.

(2) Avg. temperatures are shown in ^{o}F.

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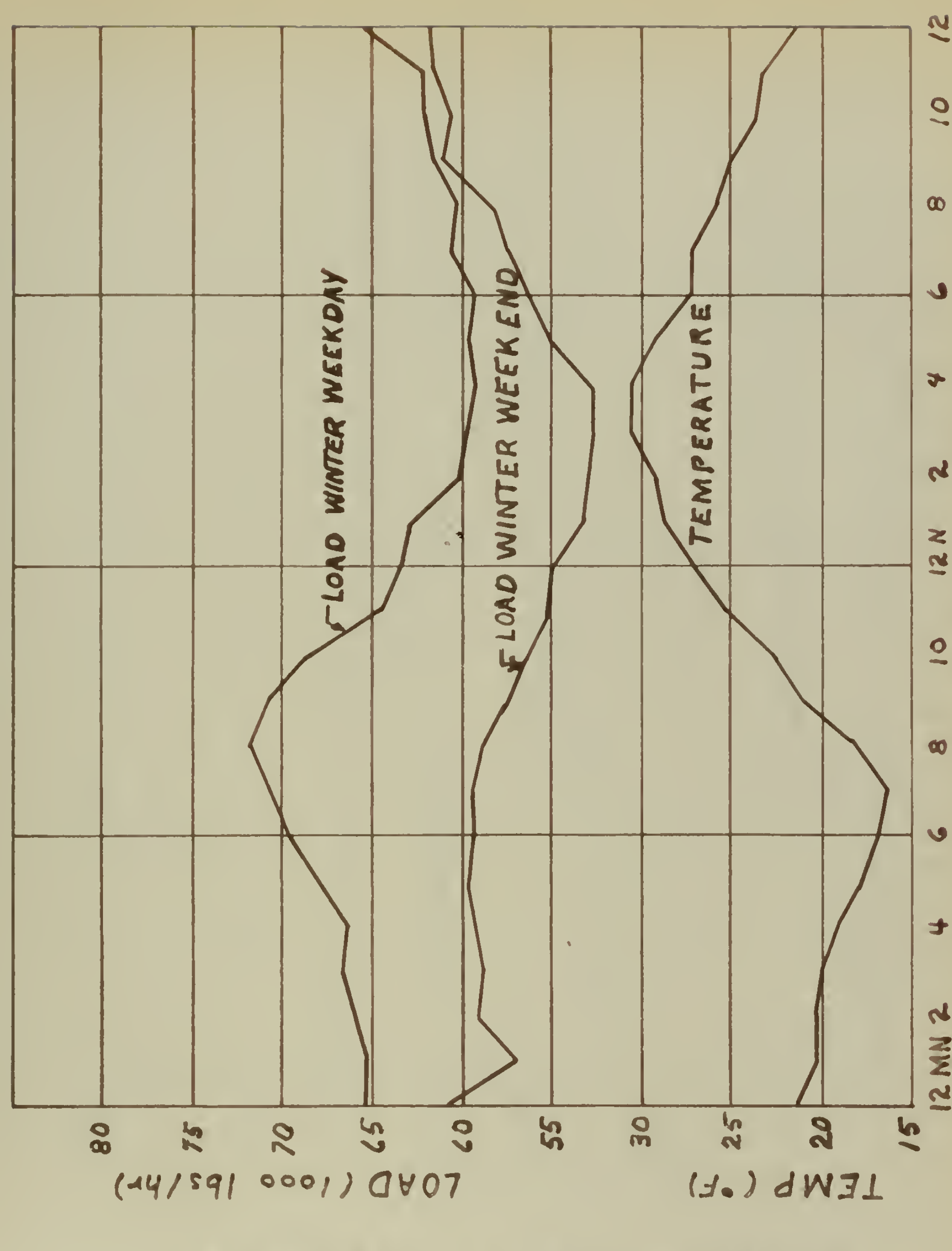
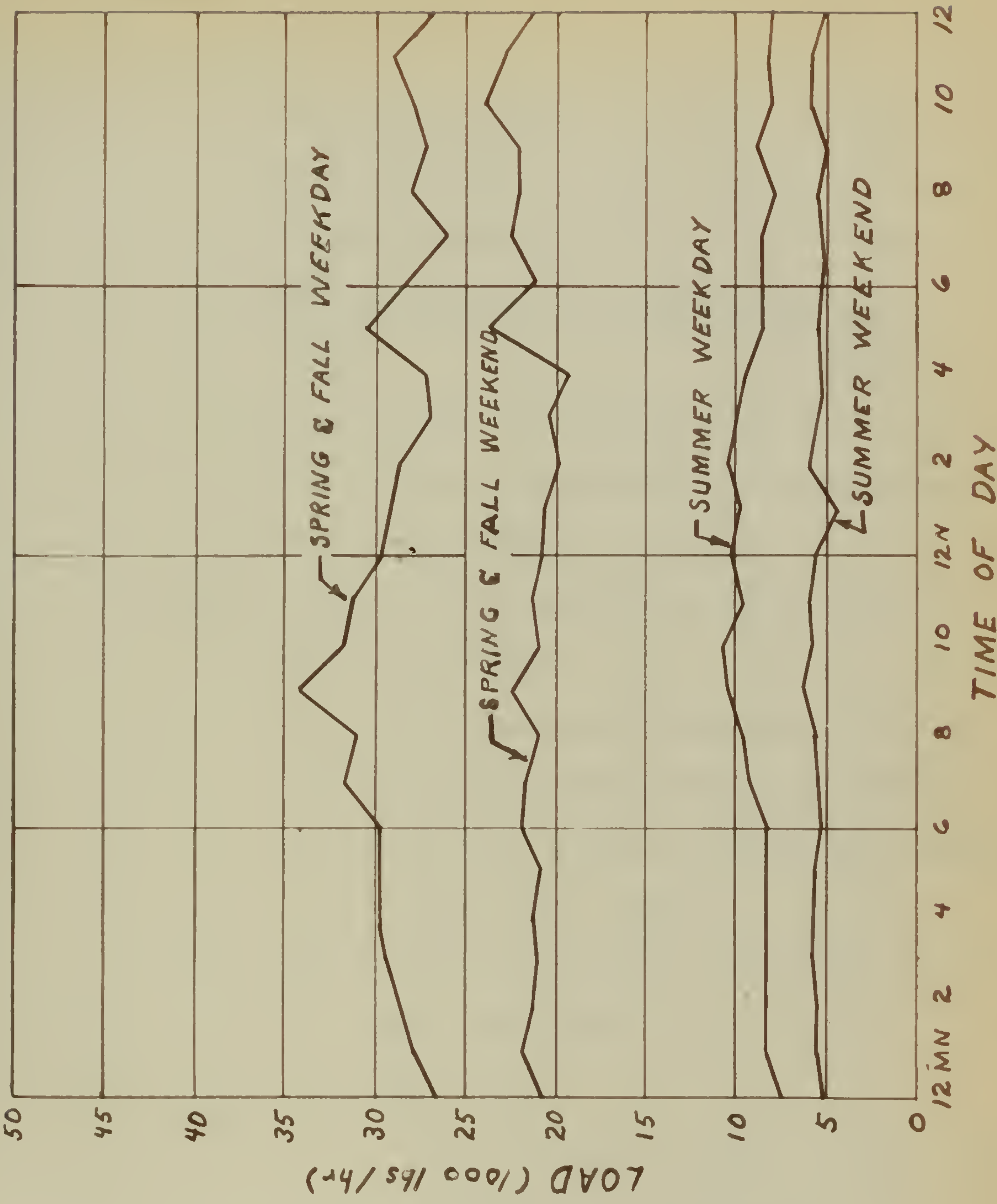


TYPICAL LOAD CURVES
AND
AVG. OUTSIDE TEMP.

FIGURE 12



TYPICAL LOAD CURVES

FIGURE 13

IV. Auxiliary steam consumption

A. Summary

1.	Feed water heating	11.09
2.	Fuel oil heating	0.37
3.	Steam atomization of fuel	1.50
4.	Miscellaneous uses, hot water, etc.	1.00
	TOTAL	13.96

An auxiliary steam consumption of 14% of the steam generated will be used in estimating the auxiliary steam load for all remaining calculations.

B. Data for estimation of auxiliary steam consumption

1. Feed water heating

a. Heater water inlet temperature 110°F

b. Heater water outlet temperature 230°F

c. Steam inlet pressure 7psig (reduced through a turbine from 115psig)

d. Assume actual turbine work is 80% of ideal work. (see Figure 14)

e. Calculations:

boiler pressure = 130 psia $\quad h_{BP} = 1191.7$

heater pressure = 22 psia $\quad S_{BP} = 1.5812$

(1) Ideal change in enthalpy through turbine (entropy is constant)

$$1.5812 = 1.7242 - x(1.3811)$$

x = quality of steam

$x = 0.1035$

$h_2 = 1158.1-(.1035)(956.8) = 1060.1$

(2) Enthalpy at inlet of heater

$\Delta h \text{ ideal} = 1191.7-1060.1 = 131.6$

$\Delta h \text{ actual} = (131.6)(.80) = 105.3$

or

enthalpy of steam entering heater

$h_2 = 1086.4$

(3) By making a balance on the heater, the weight of steam required for water heating can be found.

$(w)(1086.4) + (1-w)(77.9) = 1(198.2)$

where w = weight of steam through turbine per pound of steam generated

w = 0.1109 or 11.09% of steam generated

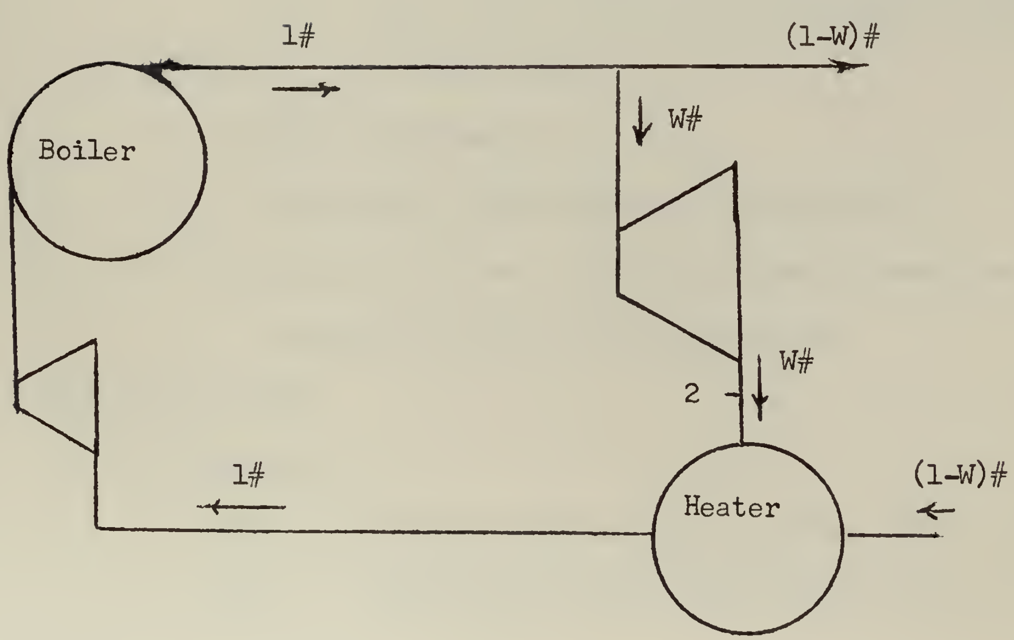


Figure 14 Schematic of Water Cycle

2. Fuel oil heating

   a. Fuel oil inlet temperature $80^{\circ}F$

   b. Fuel oil outlet temperature $185^{\circ}F$

   c. Steam inlet pressure 7psig

   d. Steam exhaust 7psig saturated liquid

   e. Specific heat of oil 0.5 Btu per lb.

   f. Calculation of percent steam consumption for the heating fuel oil

   x = lb. of steam

   (1 lb. of fuel oil)(185 - 80)(0.5) = x(1191.7 - 201.3)

   $$x = 0.053 \frac{\text{lbs. of steam}}{\text{lb. of oil}} = 0.442 \frac{\text{lbs. of steam}}{\text{gal. of oil}}$$

   On an annual basis:

   $$\frac{281{,}411{,}151 \text{ lbs. of steam}}{2{,}383{,}288 \text{ gals. of oil}} = 118 \frac{\text{lb. of steam}}{\text{gal. of oil}}$$

   Thus 0.37% of the steam generated is required to heat oil.

3. Steam atomization

   Estimated at 1½% of the steam generated*

4. Domestic hot water and other miscellaneous uses are estimated at 1% of steam generated.

V. Steam loads 1959

A. Line loss

Based on weekend loads during the summer months, as shown on typical load curves, 5400 lbs. per hr. or

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*Perry's Chemical Engineering Handbook.

47,304,000 lbs. of steam annually are required to supply line losses.

B. Hot water load

Based on the assumption that the hot water demand is 33% of the installed capacity.

(0.33)(1998 lbs. per hr)(365 days)(24 hrs) =

5,734,160 lbs. of steam annually for hot water

C. Process steam loads

Based on the typical load curves for weekdays in the summer with a correction for line losses and a 16 hour workday, the process steam load is found to be:

(3700 lbs. per hr)(16 hrs)(365 days) =

21,700,000 lbs. of steam annually

D. Heating load

Based on total steam generated, less the sum of auxiliary steam load, line loss, hot water load and process steam load

auxiliary load = 39,397,561

heating load = 167,267,490 lbs. of steam annually

VI. Annual operating costs

A. Fuel oil

Based on the current fuel oil rate of $0.0575 per gal. of fuel oil

(2,383,288 gals.)(0.0575) = $137,039.

B. Water

1. Unit cost of water

$0.25/1000 gal. - first 12,000,000 gals.

$0.15/1000 gal. after 12,000,000 gals. over a 6 month period

2. 1959 usage 10,738,300 gals.

3. Cost of water for 1959 $2684.

C. Cost of electrical power

1. Unit cost of electricity $0.01 per KW-hr

2. Cost of electricity for 1959

cost = (KW demand)(load factor)(hrs operated)(power rate)

KW demand = 112.5 KW based on connected electrical load for peak steam load of 150,000 lb. per hr

Load factor is based on the percent of plant output compared to plant capacity =

$$\frac{\text{lbs. of steam generated annually}}{\text{lbs. of steam that could be generated at constant load of 150,000 lbs./hr}}$$

hours operated = 8760 hrs per year

power rate = $0.01 per KW-hr

cost of electric power = $2105. per annum

D. Operation supplies

Based on the total operation and maintenance supplies costs for 1959 of $7500. an arbitrary estimate of $1500. is made for operation supplies.

E. Operations labor

Title	Number	Wages	Fringe Benefits	Total
Enginemen	4	$23,546.		
Leading firemen	4	21,191.		

Title	Number	Wages	Fringe Benefits	Total
Firemen	8	$38,216.		
Steam fitters	4	7,741.		
TOTAL	20	$90,694.	$4,535.	$95,229.

F. Maintenance labor

Title	Number	Wages	Fringe Benefits	Total
Maint. men	3	$15,893.	$ 794.	$16,687.

G. Maintenance supplies

Maintenance supplies $6000. (see D above)

H. Supervisor and clerical costs

Title	Number	Wages	Fringe Benefits	Total
Plant manager	1	$ 8,570.		
Clerk	1	3,590.		
TOTAL	2	$12,160.	$ 608.	$12,768.

I. Office supplies

Estimated at $200. per annum

J. Total operating cost

$274,208. per annum operating costs

VII. Cost of system

A. Cost of central plant $1,890,699.

(based on historical records)

B. Cost of distribution system

1. Based on historical records $122,295.

2. Estimated cost of 1946 construction

Based on 1960 construction costs scaled to 1943 costs by Handy Construction Cost Index.

Material:

3350 ft - $1\frac{1}{2}$" pipe and covering	-	\$ 2,589.
1640 ft - 2" pipe and covering	-	1,546.
940 ft - $2\frac{1}{2}$" pipe and covering	-	1,149.
588 ft - 3" pipe and covering	-	837.
5430 ft - 4" pipe and covering	-	11,619.
730 ft - 5" pipe and covering	-	2,164.
2460 ft - 6" pipe and covering	-	8,935.
1610 ft - 8" pipe and covering	-	8,345.
700 ft - 10" pipe and covering	-	4,597.
630 ft - 12" pipe and covering	-	5,481.
390 ft - 14" pipe and covering	-	3,663.
TOTAL		\$50,925.
Cost of installation*, etc. (1.5)(material cost)		76,387.
TOTAL		\$127,312.
1946 cost		\$ 70,733.

Cost of conduit and tunnel

1960 ft. at \$18.40 per ft. in 1960

1946 cost \$20,500

Total 1946 estimated cost \$ 91,233.

3. Total distribution system cost \$442,295.

VIII. Fixed cost 1959

A. Depreciation

Based on 20 years straight line depreciation

Cost of central plant \$1,890,699.

*See Appendix D for basis of installation costs.

Cost of distribution system	\$ 442,295.
TOTAL	\$2,332,994.

$$\frac{2,332,994}{20} = \$116,649. \text{ per annum}$$

B. Interest

Based on a $4\frac{1}{2}\%$ interest rate

$$\left(\frac{20 + 1}{2(20)}\right)(0.045)(\$2,332,994) = \$55,117.$$

C. Taxes

Based on the location of the plant and 1959 tax rate of \$68.54/1000.

$$(\$2,332,994)\left(\frac{68.54}{1000}\right) = \$159,903.$$

D. Insurance

Based on an evaluation by the New York Underwriters of \$0.044/100.

$$(\$2,332,994)\left(\frac{0.044}{100}\right) = \$1027.$$

E. Total fixed costs

\$332,696. per annum

SCHEDULE OF RETURN PUMPS			
PUMP NO.	BLDG. NO.	CAP. (GPM)	HEAD
P-1	6	9	35'
P-2	2	9	69'
P-3	1	30	20'
P-4	10	30	80'
P-5	115	30	100'
P-6	110	375	40#
P-7	110	60	40#
P-8	15	UNKNOWN	
P-9	9	3	40'
P-10	22	60	60#
P-11	19	6	40'
P-12	23	12	90'
P-13	35	97.5	40'
P-14	38	80	60#
P-16	20	60	60#
P-17	35	23	60#
P-18	40	23	60#
P-19	121	12.5	95'
P-20	40	23	60#
P-21	10	12	23'
P-22	136	200	10#
P-23	105	6	46'
P-24	124	22	40#
P-25	130	9	40#
P-26	124	80	40#
P-27	120	23	40#
P-28	41	2	60#
P-29	40	23	60#
P-30	21	7.5	20#
P-31	110	37.5	20#
P-32	10	30	40#
P-33	44	15	100'
P-34	44	6	100'

LEGEND

- HL ~ HEATING LOAD
- H.W. ~ INSTALLED HOT WATER LOAD
- P.S. ~ INSTALLED PRESSURE STEAM LD.
- —— STEAM LINES
- – – – RETURN LINES
- PUMPS
- PRESSURE REDUCING STA.S
- VALVES

NOTE: ALL LOADS EXPRESSED IN LB.S PER HR DESIGN CONDITIONS

FIGURE 15

SCHEMATIC DIAGRAM EXISTING STEAM DISTRIBUTION SYSTEM-ALTERNATIVE #1

THE EVALUATION OF A CENTRAL HEATING SYSTEM FOR AN INDUSTRIAL FACILITY

JUNE 1960	W. J. BURNS

SCALE: NONE

APPENDIX C

Calculation of Cost with Reduced Personnel Level (Alternative 2)

I. Basis of alternative 2

A. Under this alternative no additional capital investment is required. This alternative simply reduces the operating crew to the minimum safe level consistant with current practice.

B. Steam loads are based on calculated loads rather than historical 1959 loads so that a comparison of the alternatives that will be investigated can be made.

II. Steam consumption and generation

A. Line loss

Same as historical 1959 - 47,304,000 lbs. per annum

B. Hot water load

Same as historical 1959 - 5,734,160 lbs. per annum

C. Process load

Same as historical 1959 - 21,708,000 lbs. per annum

D. Heating load

1. Building groups A,B,C,D, and E

6319° days

$$(79{,}814 \frac{\text{lbs. steam}}{\text{design hr}})(\frac{24 \text{ hr}}{80^{\circ}\text{F design}})(6319) =$$

151,235,136 lbs. per annum

For annual cost use of factor of 0.875 for -10°F in accordance with HVAC Guide; thus for groups A,

[illegible]

B,C,D, and E 132,330,644 lbs. per annum

2. Group D_1

Based on 212 heating days and 35^{o} avg. temperature

$$\frac{(44,565 \text{ lbs. per design hr})(212 \text{ days})(20^{o}F)(.875)}{80^{o}F} =$$

49,600,845 lbs. per annum

Total heating load 181,931,499 lbs. per annum

E. Auxiliary steam

(0.14)(steam generated) + (external load) = steam generated

auxiliary steam = (0.16279)(external load)

load = 256,677,659

auxiliary steam = 41,784,556 lbs. per annum

F. Summary

1.	Line loss	47,304,000
2.	Hot water load	5,734,160
3.	Process load	21,708,000
4.	Heating load	181,931,499
5.	Auxiliary load	41,784,556
	Total steam generation	298,462,215 lbs. per annum

III. Annual operating costs

A. Fuel oil

Based on the 1959 cost ($0.0575 per gal. of oil) of 4.8801×10^{-4} \$/lb. of steam generated

$145,678. per annum

B. Water

Based on the 1959 cost of 9.5385×10^{-6} \$/lb. of steam generated $ 2,846. per annum

C. Electric power

Based on 1959 cost of 7.5×10^{-6} \$/lb. of steam generated $ 2,238. per annum

D. Operation supplies

Estimated $ 1,500. per annum

E. Operations labor

Title	Number	Wages	Fringe Benefits	Total
Enginemen	5	$29,431.		
Firemen	4	19,108.		
TOTAL	9	$48,539.	$2,427.	$50,966. per annum

F. Maintenance labor

The same as historical 1959 $ 16,687. per annum

G. Maintenance materials

Estimated $ 6,000. per annum

H. Supervision and clerical costs

The same as historical 1959 $ 12,768. per annum

I. Office materials

Estimated $ 200. per annum

J. Total operations cost $238,883. per annum

IV. Cost of system

The same as historical 1959 $2,332,994. per annum

V. Fixed cost

The same as historical 1959 $ 332,696. per annum

APPENDIX D

Installation of a New Distribution System (Alternative 3)

I. Basis for alternative 3

A. Under this alternative an additional capital investment is required. Considered is a steam distribution system adequate to serve the load without duplication or excessive sizing of lines.

B. Steam loads are based on calculated steam loads.

II. Steam consumption and generation

A. Line loss

Based on the manufacturer's data* for recommended insulation for the pipe line sizes and lengths listed under IV below

1,666 lbs. per hr in heating season (212 days)

501 lbs. per hr remainder of year (153 days)

10,316,788 lbs. per annum

B. Hot water load

Same as historical 1959 5,734,160 lbs. per annum

C. Process load

Same as historical 1959 21,708,000 lbs. per annum

D. Heating load

Same as listed in Appendix C, section II-D

181,931,499 lbs. per annum

*Johns-Manville Insulations Catalog AIA File No.37-D-2.

E. Auxiliary load

14% of steam generated

External load =	219,690,447 lbs. per annum
Auxiliary load =	35,763,407 lbs. per annum

F. Summary

1.	Line loss	10,316,788
2.	Hot water load	5,734,160
3.	Process load	21,708,000
4.	Heating load	181,931,499
5.	Auxiliary load	35,763,407
	Total steam generation	255,453,854 lbs. per annum

III. Annual operating costs

A. Fuel oil

Based on 1959 cost of 4.8801×10^{-4} \$/lb. of steam generated — \$124,684. per annum

B. Water

Based on 1959 cost of 9.5385×10^{-6} \$/lb. of steam generated — \$ 2,436. per annum

C. Electric power

Based on 1959 cost of 7.5×10^{-6} \$/lb. of steam generated — \$ 1,915. per annum

D. Operation supplies

Same as Alternative 2 — \$ 1,500. per annum

E. Operations labor

Same as Alternative 2 — \$ 50,966. per annum

F. Maintenance labor

Same as Alternative 2 $ 16,687. per annum

G. Maintenance materials

Same as Alternative 2 $ 6,000. per annum

H. Supervision and clerical costs

Same as Alternative 2 $ 12,768. per annum

I. Office material

Same as Alternative 2 $ 200. per annum

J. Total operations cost $217,156. per annum

IV. Cost of system

A. Plant

Same as Alternative 1 $1,890,699.

B. Distribution system

1. Cost of pipe and covering

Size	Length	Unit Price	Cost
1 "	3260	$ 0.5564	$ 1,814.
$1\frac{1}{4}$"	1725	0.6623	1,142.
$1\frac{1}{2}$"	2937	0.7529	2,211.
2 "	1375	0.9147	1,258.
$2\frac{1}{2}$"	3237	1.3904	4,501.
3 "	1837	1.6887	3,102.
4 "	4512	2.2912	10,338.
5 "	2225	3.3446	7,742.
6 "	2012	4.0121	8,072.
8 "	2112	5.1831	10,946.
10 "	725	6.5677	4,762.
12 "	425	8.6998	3,697.

Size	Length	Unit Price	Cost
14 "	865	$10.730	$ 9,281.
TOTAL			$68,866.

Note: (1) 25% has been added to the length of piping to account for variations in horizontal measurements.

(2) Unit cost is in $/ft. for pipe and covering materials only, based on costs from Johns-Manville and Walworth Valve Company catalogs.

(3) Length of pipe to be used for expansion joints of the loop style are not included under pipe but are in the tabulation of expansion joint costs.

2. Cost of fittings

Size	Number	Unit Price	Cost
1 "	85	$ 0.96	$ 82.
$1\frac{1}{4}$"	46	1.15	53.
$1\frac{1}{2}$"	70	1.39	97.
2 "	39	1.73	67.
$2\frac{1}{2}$"	64	2.79	179.
3 "	23	4.02	92.
4 "	83	6.24	518.
5 "	51	14,12	720.
6 "	40	14.12	565.
8 "	22	26.53	584.

Size	Number	Unit Price	Cost
10 "	9	$ 55.23	$ 497.
12 "	7	82.92	580.
14 "	17	131.37	2,233.
TOTAL			$6,267.

Note: (1) Fittings were estimated on the following basis - one fitting at each horizontal turn and three fittings at each building entrance. (detail of a typical building entrance is shown in Figure 17 of Appendix D)

(2) Unit price is based on Walworth Valve Company Price Sheet WC-5 of January 28, 1960.

3. Cost of valves

Size	Number	Unit Price	Cost
1 "	12	$ 9.60	$ 115.
$1\frac{1}{4}$"	1	11.40	11.
$1\frac{1}{2}$"	3	13.00	39.
2 "	3	16.80	50.
$2\frac{1}{2}$"	12	26.60	319.
3 "	6	37.20	223.
4 "	15	76.00	1,140.
5 "	5	129.20	646.
6 "	3	129.20	388.
8 "	2	214.20	428.

Size	Number	Unit Price	Cost
12 "	1	$503.80	$ 504.
TOTAL			$3,863.

Note: (1) Unit prices are based on Walworth Price Schedule No. 9-F of December 10, 1959.

4. Cost of expansion joints

Size	Number	Unit Price	Cost
Single end - 4" traverse			
2"	1	$ 175.20	$ 175.
4"	1	243.20	243.
5"	3	279.20	838.
6"	1	312.00	312.
8"	1	404.00	404.
10"	1	534.40	534.
14"	1	840.00	840.
Single end - 8" traverse			
$1\frac{1}{4}$"	1	176.20	167.
4"	3	252.80	758.
6"	1	323.20	323.
8"	2	416.80	834.
12"	1	703.20	703.
Double end - 4" traverse			
1"	1	305.60	306.
$1\frac{1}{4}$"	1	305.60	306.
$1\frac{1}{2}$"	1	305.60	306.
$2\frac{1}{2}$"	4	360.00	1,440.

Size	Number	Unit Price	Cost
3"	4	$ 393.60	$ 1,574.
4"	1	467.20	467.
5"	6	537.60	3,226.
6"	3	601.60	1,805.
14"	1	1,609.60	1,610.
Double end - 8" traverse			
4"	1	486.40	486.
6"	1	624.00	624.
8"	1	806.40	806.
10"	1	1,063.20	1,063.
14"	1	1,668.00	1,668.
Expansion loops			
1"	1	12.19	12.
$1\frac{1}{4}$"	1	19.17	19.
$1\frac{1}{2}$"	4	24.58	98.
2"	1	36.19	36.
$2\frac{1}{2}$"	2	55.65	111.
4"	4	102.86	411.
5"	1	184.57	185.
TOTAL			$22,690.

Note: (1) Unit prices for joints are from Yarnall-Waring Company Price List EJ No. 24 of January 1, 1960.

(2) Unit price of loops is based on the following table:

Size	Fitting per Loop	Length of Pipe	Unit Cost
1"	4	15 ft.	$ 12.19
$1\frac{1}{4}$"	4	22 ft.	19.17
$1\frac{1}{2}$"	4	25 ft.	24.58
2"	4	32 ft.	36.19
$2\frac{1}{2}$"	4	32 ft.	55.65
4"	4	34 ft.	102.86
5"	4	38 ft.	184.57

5. Cost of pumps

Pump No.	Bldg. No.	Cap.(EDR)	Head (psi)	Cost
1	40	40,000	100	$ 660.
2	38	6,000	75	372.
3	23	4,000	75	332.
4	20	40,000	75	636.
5	25	40,000	75	636.
6	24	1,000	75	325.
7	35	65,000	40	644.
8	15	16,000	75	520.
9	21	6,000	75	372.
10	108	12,000	75	470.
11	115	20,000	40	455.
12	6	6,000	75	372.
13	2	5,000	75	372.
14	10	4,000	75	332.
15	10	6,000	50	335.
16	110	30,000	50	512.

Pump No.	Bldg. No.	Cap.(EDR)	Head(psi)	Cost
17	110	65,000	50	$ 684.
18	110	30,000	50	512.
19	121	12,000	30	363.
20	123	4,000	30	492.
21	126	40,000	30	438.
22	125	40,000	30	492.
23	130	4,000	30	249.
24	30	5,000	15	160.
25	22	2,000	15	150.
26	124	4,000	30	249.
27	112	1,000	15	150.
28	114	1,000	15	150.
29	120	6,000	15	160.
30	17	6,000	15	160.
31	9	1,000	15	150.
32	16	1,000	15	150.
33	105	5,000	15	160.
34	122	3,000	15	150.
TOTAL				$12,364.

Note: (1) Cost of pumps is based on the use of Sterling 3500 series. Condensate pump price includes tank, pump, motor, controls, and base.

6. Cost of traps

70 traps at $22.31 each $1,562.

7. Cost of overhead support between buildings

Building to Building		Length	Wire Cost	Hardware Cost	Total
40	38	70	$23.	$ 20.	$ 43.
20	25	40	13.	20.	33.
25	30	50	16.	20.	36.
20	23	20	7.	20.	27.
23	22	80	26.	20.	46.
20	24	60	20.	20.	40.
24	35	50	16.	20.	36.
35	105	40	13.	20.	33.
105	103	40	13.	20.	33.
105	110	80	26.	20.	46.
110	125	120	40.	290.*	330.
110	121	40	13.	20.	33.
110	112	20	7.	20.	27.
110	115	30	10.	20.	30.
115	120	50	16.	20.	36.
115	114	60	20.	20.	40.
110	108	20	7.	20.	27.
108	14	30	10.	20.	30.
21	15	40	13.	20.	33.
15	16	40	13.	20.	33.
16	17	40	13.	20.	33.
17	9	30	10.	20.	30.
TOTAL					$1,055.

*Intermediate support is necessary.

Note: (1) Hardware consists of turnbuckles, eye-bolts, and backing plates.

8. Cost of conduit

1090 ft. at $7.36 per ft. $8,022.0

9. Summary of material costs

a.	Pipe	$ 68,866.
b.	Fittings	6,267.
c.	Valves	3,863.
d.	Expansion joints	22,690.
e.	Pumps	12,364.
f.	Traps	1,562.
g.	Overhead suspension	1,055.
h.	Conduit	8,022.
i.	Misc. materials* 15%	18,703.
	TOTAL	$143,392.

10. Installation cost

To arrive at labor cost, a typical section of the line was considered (service to Buildings 20,25, and 30). A detailed estimate of cost was made for this section.

a. Material costs

(1) Pipe and covering

Size	Length	Cost
6"	180 ft.	$722.
5"	240 ft.	802.

*Includes such materials as sleeves, pipe supports, etc.

Size	Length	Cost
3"	300 ft.	$ 540.
TOTAL		$2,064.

(2) Fittings

Size	Number	Cost
6"	2	$ 28.
5"	8	113.
3"	7	28.
TOTAL		$169.

(3) Valves

Size	Number	Cost
4"	2	$152.
3"	1	37.
TOTAL		$189.

(4) Expansion joints

Size	Number	Cost
6"	1	$601.60
3"	1	393.60
TOTAL		$995.

(5) Traps

3 traps $ 67.

(6) Overhead suspension

Bldg. 30 to 25	$ 37.
Bldg. 25 to 20	33.
TOTAL	$ 70.

(7) Miscellaneous materials

15% of other materials $ 533.

(8) Cost of materials

1 + 2 + 3 + 4 + 5 + 6 + 7 = 8 $4,087.

b. Labor costs

Operation	Unit Time of Operation	Man Days Mechanic	Man Days Helper
(1) Place material on job		1.0	1.0
(2) Supports	80 supports, cut and thread rods 3/hr	3.0	
	mount supports 2/hr	3.0	3.0
(3) Place pipe in supports	2 lengths/hr	2.5	2.5
(4) Weld joints	3 joints/day	13.0	13.0
(5) Insulation	20 ft/hr straight pipe	5.0	5.0
	3 hr/fitting	3.0	3.0
(6) Clean up		1.0	1.0
TOTAL		31.5	28.5

(7) Labor mechanic $7.50/hr $60.00/day

	$1,890.
Helper $5.50/hr $44.00/day	1,254.
TOTAL	$3,144.

c. Summary of contract costs

(1) Material	$4,087.
(2) Labor	3,144.
(3) Contingency (10% of labor)	314.

(4) Overhead (10% of (1), (2), and (3)) $ 754.

(5) Profit (15% of (1), (2), and (4)) 1,244.

TOTAL $9,543.

On this basis it can be seen that 1.5 x material cost is approximately the cost of labor, contingency, overhead, and profit.

Installation = (1.5)(material cost) $215,088.

d. Summary of distribution system cost

(1)	Material cost	$143,392.
(2)	Installation cost	215,088.
	TOTAL	$358,480.

C. Total cost

1.	Plant	$1,890,699.
2.	Distribution	358,480.
	TOTAL	$2,249,179.

V. Fixed costs

A. Depreciation

$\frac{\$2,249,179.}{20 \text{ years}}$ $112,459. per annum

B. Interest

$4\frac{1}{2}\%$ interest rate

$\left(\frac{20+1}{20}\right)(0.045)(\$2,249,179.)$ $ 53,137. per annum

C. Taxes

$\left(\frac{\$68.54}{\$1000}\right)(\$2,249,179.)$ $154,158. per annum

D. Insurance

$\left(\frac{\$0.044}{\$100}\right)(\$2,249,179.)$ $ 990. per annum

E. Total fixed costs

A ≠ B ≠ C ≠ D = E $320,744.per annum

SCHEDULE OF PUMPS			
PUMP NO.	BLDG	CAPACITY (EDR)	HEAD (PSI)
P-1	40	40,000	100
P-2	38	6,000	25
P-3	23	4,000	25
P-4	20	40,000	75
P-5	25	40,000	75
P-6	24	1,000	75
P-7	35	65,000	40
P-8	15	16,000	75
P-9	21	6,000	75
P-10	108	12,000	75
P-11	115	20,000	40
P-12	6	6,000	75
P-13	2	5,000	75
P-14	10	4,000	75
P-15	10	6,000	50
P-16	110	30,000	50
P-17	110	65,000	50
P-18	110	30,000	50
P-19	121	12,000	30
P-20	121	4,000	30
P-21	126	40,000	30
P-22	125	4,000	30
P-23	130	4,000	30
P-24	30	5,000	15
P-25	22	2,000	15
P-26	124	4,000	30
P-27	112	1,000	15
P-28	114	1,000	15
P-29	120	6,000	15
P-30	17	6,000	15
P-31	9	1,000	15
P-32	16	1,000	15
P-33	105	5,000	15
P-34	122	3,000	15

SCHEDULE OF EXPANSION JOINTS		
TYPE	DESCRIPTION	TRAVERSE
A	SINGLE END	4"
B		8"
C	DOUBLE END	4"
D		8"

SCHEDULE OF EXPANSION LOOP		
PIPE SIZE (IN)	LEG LENGTH (FT.)	WIDTH (FT.)
1	6	3
1 1/4	9	4
1 1/2	9	4
2	10	5
2 1/2	10	5
4	14	6
5	16	6

LEGEND

HL ~ HEATING LOAD
H.W. ~ INSTALLED HOT WATER LOAD
P.S. ~ INSTALLED PRESSURE STEAM LOAD
— STEAM LINES
--- RETURN LINES
PUMPS
PRESSURE REDUCING STA.S
VALVES
EXPANSION JOINT
NOTE: ALL LOADS EXPRESSED IN LBS PER HR. DESIGN CONDITIONS

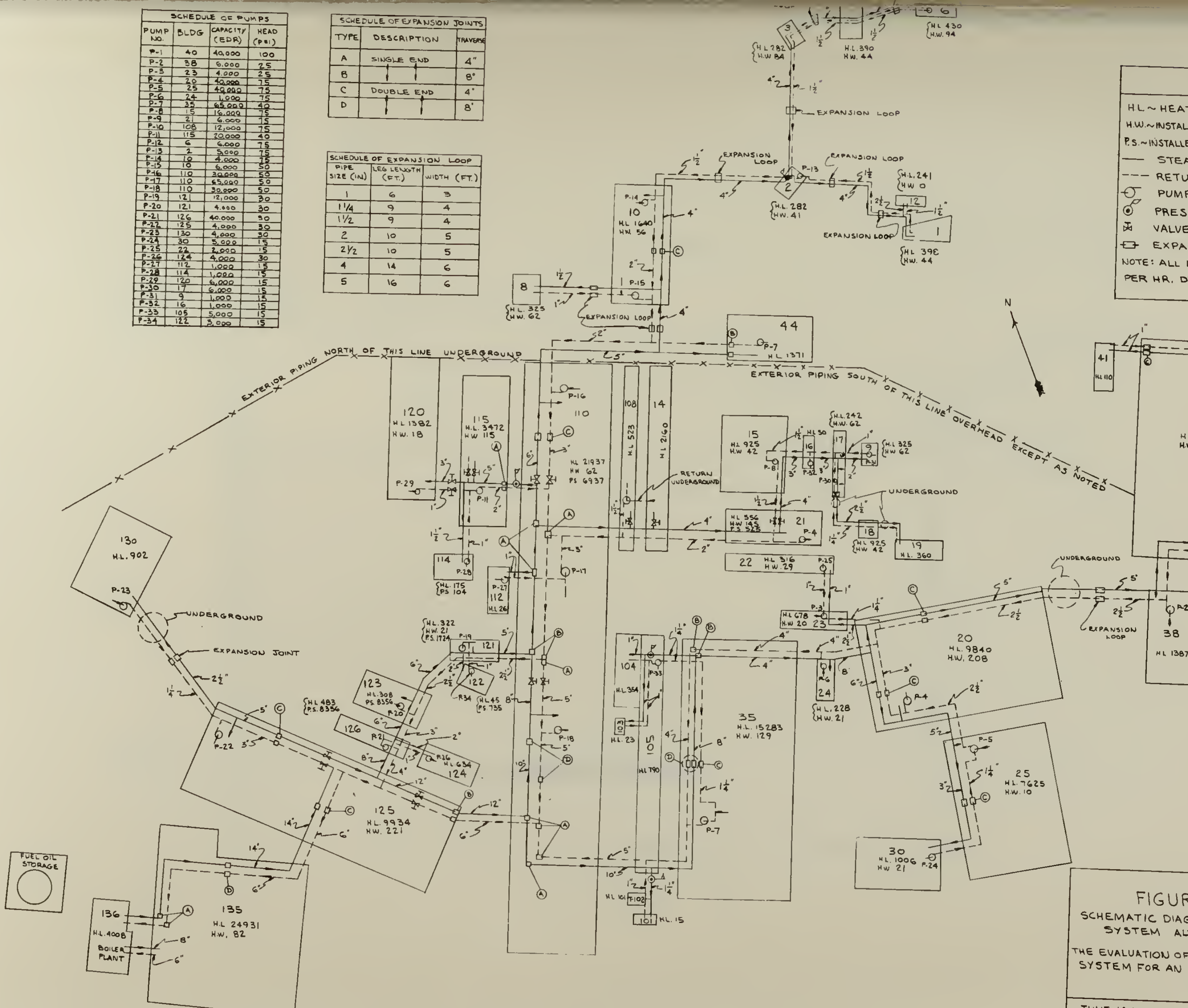
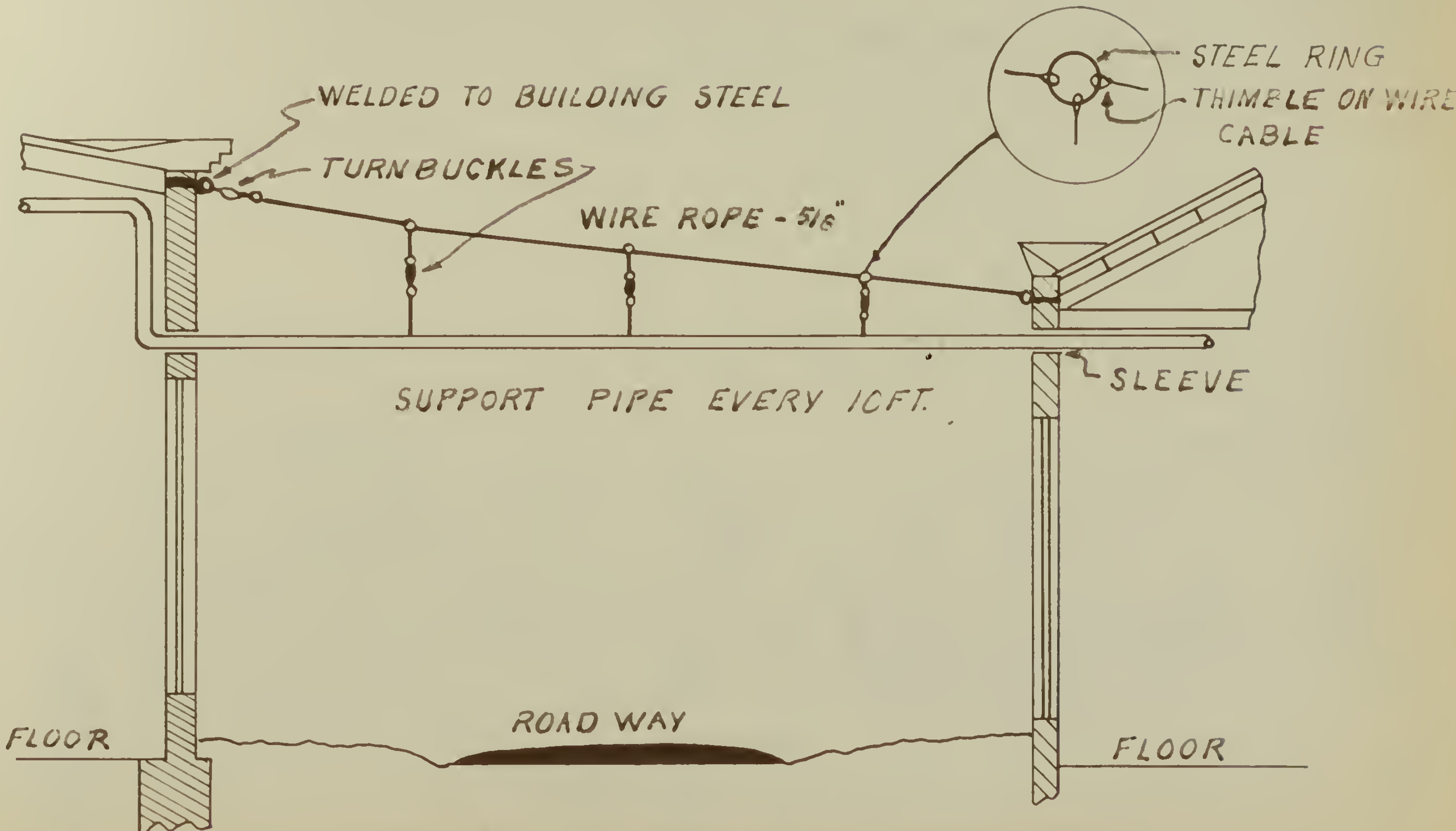


FIGURE 16
SCHEMATIC DIAGRAM-NEW DISTRIBUTION SYSTEM ALTERNATIVE #3
THE EVALUATION OF A CENTRAL HEATING SYSTEM FOR AN INDUSTRIAL FACILITY

JUNE 1960	W.J. BURNS
SCALE: NONE	



TYPICAL OVERHEAD SUSPENSION
SCALE 1/8" = 1'
FIGURE 17

TYPICAL ANCHOR DETAILS

BASED ON THE RECOMENDATIONS OF THE AMERICAN GILSULATE COMPANY

ANCHOR DIMENSIONS

PIPE IN.	D IN.	L IN.	W IN.	ROD IN.
1	15	30	20	3/8
2	19	40	20	1/2
3	23	50	20	5/8
4	24	55	20	3/4
5	27	60	20	7/8

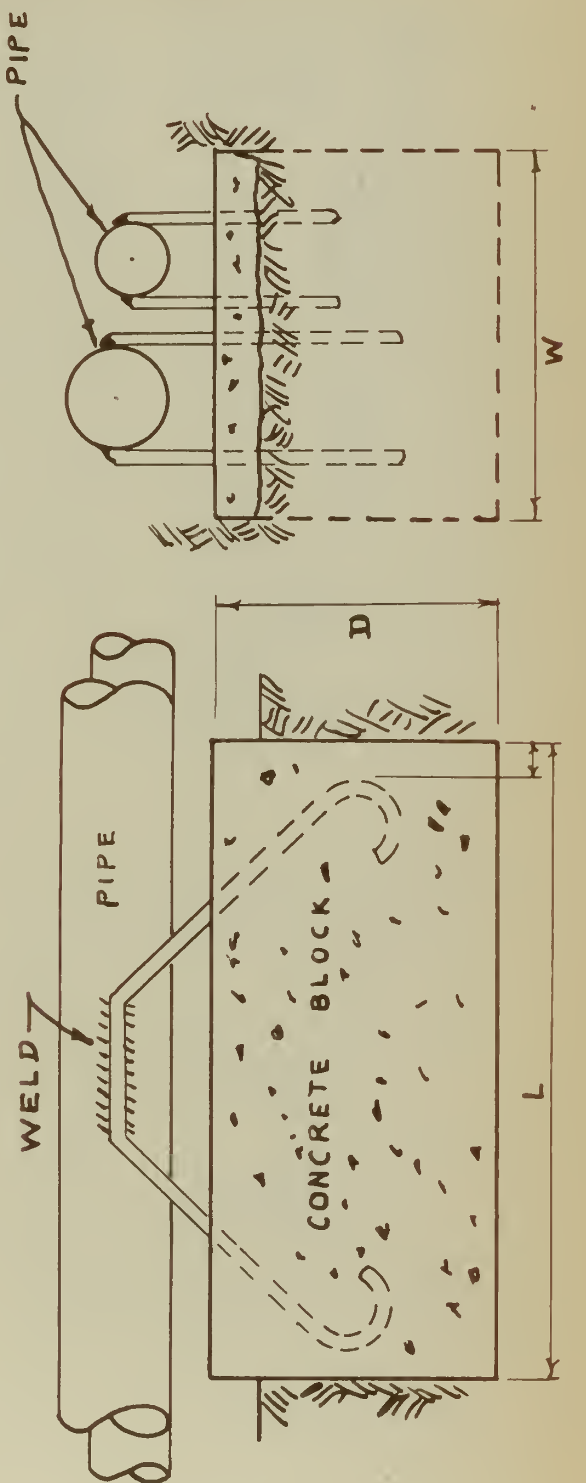
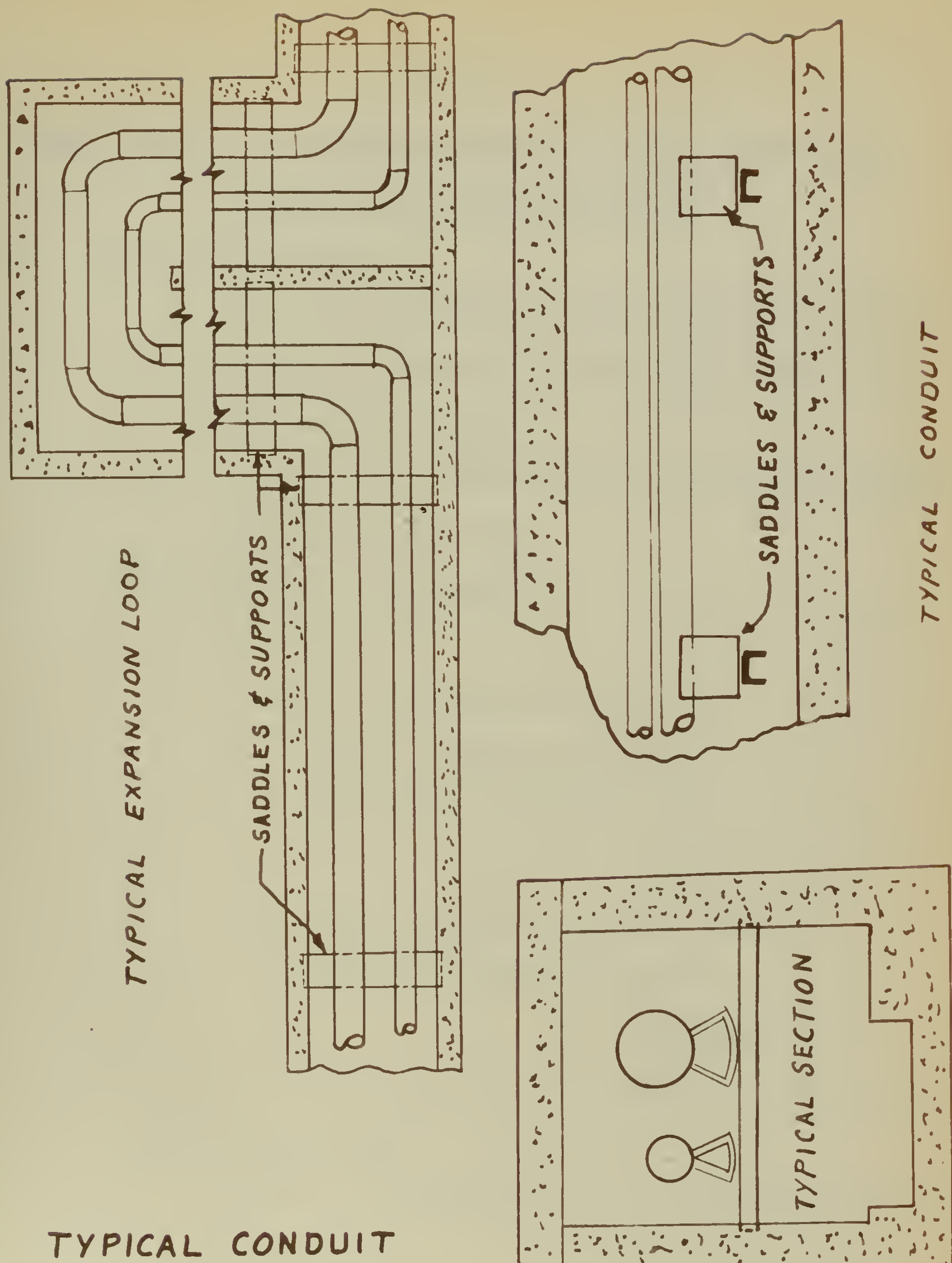


FIGURE 18



TYPICAL CONDUIT DETAILS

FIGURE 19
NO SCALE

APPENDIX E

Installation of an Automatic Boiler for Process Load during the Non-heating Season (Alternative 4)

I. Basis of Alternative 4

A. Under this alternative an additional capital investment is required. The existing distribution system is utilized wherever possible.

B. The steam loads used under this alternative are based on calculated steam loads.

II. Steam consumption and generation

A. Line loss

Based on a 212 day heating season

1. Line loss during heating season

(212 days)(24 hrs)(5400 lb./hr)

27,475,200 lbs.

2. Line loss during non-heating season

(153 days)(24 hrs)(373 lb./hr)

1,369,656 lbs.

28,844,856 lbs. per annum

B. Hot water load

Same as Alternative 2 — 5,734,160 lbs. per annum

C. Process load

Same as Alternative 2 — 21,708,000 lbs. per annum

D. Heating load

Same as Alternative 2 — 181,931,499 lbs. per annum

E. Auxiliary load

14% of steam generated 40,779,592 lbs. per annum

F. Summary of loads

1.	Line loss	28,844,856
2.	Hot water load	5,734,160
3.	Process load	21,708,000
4.	Heating load	181,931,499
5.	Auxiliary load	40,779,107
	Total steam generated	278,998,107 lbs. per annum

III. Annual operating costs

A. Fuel oil

Based on 1959 cost of 4.8801×10^{-4} \$/lb. of steam

\$136,154. per annum

B. Water

Based on 1959 cost of 9.538×10^{-6} \$/lb. of steam

\$ 2,661. per annum

C. Electric power

Based on 1959 cost of 7.5×10^{-6} \$/lb. of steam

\$ 2,092. per annum

D. Operation supplies

Same as Alternative 2 \$ 1,500. per annum

E. Operation labor

Title	Number	Wages	Fringe Benefits	Total
Enginemen	5	\$29,431.		
Firemen (5088 hrs)	4	11,942.		
TOTAL		\$41,373.	\$2,069.	\$43,442. per annum

F. Maintenance labor

Title	Number	Wages	Fringe Benefits	Total
Maint. Men	2	$11,125.		
Firemen (2944 hrs)	4	7,165.		
TOTAL		$18,291.	$914.	$19,205. per annum

G. Maintenance materials

Same as Alternative 2 $ 6,000. per annum

H. Supervision and clerical costs

Same as Alternative 2 $ 12,768. per annum

I. Office materials

Same as Alternative 2 $ 200. per annum

J. Total operation costs $224,022. per annum

IV. Cost of system

A. Plant $1,890,699.

B. Distribution system $ 442,295.

C. Summer system

1. Material cost

a. Pipe and insulation

Size	Length	Cost
6"	400 ft.	$1,605.
$1\frac{1}{2}$"	300 ft.	226.
TOTAL		$1,831.

b. Fittings

Size	Number	Cost
6"	16	$226.

Size	Number	Cost
$1\frac{1}{2}$"	16	$ 22.
TOTAL		$248.

c. Valves

Size	Number	Cost
12"	1	$ 504.
8"	1	350.
6"	2	258.
5"	1	129.
TOTAL		$1,241.

d. Additional support $87.

e. Boiler - to be housed in the vacant area of Building 110

Cost of equipment*

($1.25 $/lb./hr)(15,000 lb./hr) = $18,750.

f. Remove and reinsulate pipe as necessary

Size	Length	Cost to Clean	Insulation Cost
6"	340 ft.	14.40$/100 ft.	$ 473.
4"	500 ft.	14.40$/100 ft.	381.
$2\frac{1}{2}$"	90 ft.	14.40$/100 ft.	46.
2"	400 ft.	14.40$/100 ft.	183.
	1330 ft.	$192.	$1,083.

g. Summary of material costs

(1) Pipe and insulation $ 1,831.

(2) Fittings 248.

*Clever Brooks preliminary cost estimate by letter of April 28, 1960.

(3)	Valves	\$ 1,241.
(4)	Support	87.
(5)	Boiler	18,750.
(6)	Insulation	1,083.
	TOTAL	\$23,240.

h. Installation cost

1.5 x \$23,240.	\$34,860.
Cleaning pipe	192.
TOTAL	\$35,052.

i. Total cost of summer system

Material	\$23,240.
Installation	35,052.
TOTAL	\$58,292.

D. Total system cost

1.	Plant	\$1,890,699.
2.	Distribution system	442,295.
3.	Summer system	58,295.
	TOTAL	\$2,391,289.

V. Fixed costs

A. Depreciation

$\frac{\$2,391,289.}{20 \text{ years}}$ \$119,564. per annum

B. Interest

Based on $4\frac{1}{2}\%$ for 20 years

$\left(\frac{20 + 1}{2(20)}\right)(0.045)(\$2,391,289.)$ \$ 56,494. per annum

C. Taxes

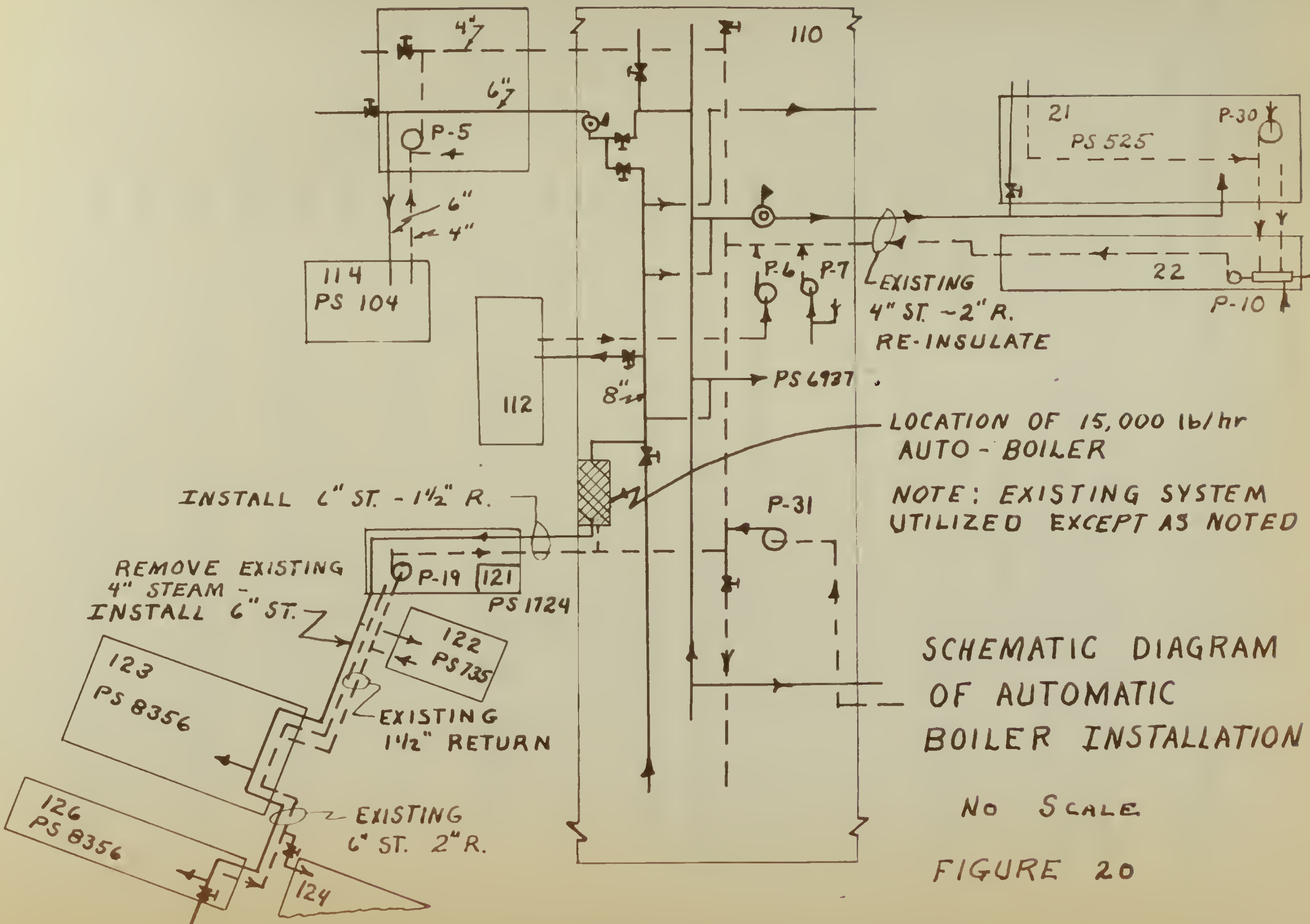
$(\frac{\$68.54}{\$1000})(\$2,391,289.)$ $163,898. per annum

D. Insurance

$(\frac{\$0.044}{\$100})(\$2,391,289.)$ $ 1,052. per annum

E. Summary of fixed costs

$A + B + C + D = E$ $341,008. per annum



SCHEMATIC DIAGRAM
OF AUTOMATIC
BOILER INSTALLATION

NO SCALE

FIGURE 20

APPENDIX F

Re-insulation of Existing Distribution System as Required (Alternative 5)

I. Basis for Alternative 5

A. Under this alternative a capital investment must be made. It is assumed that 50% of the insulation within the building has deteriorated or is non-existent.

B. The steam loads used under this alternative are based on the calculated steam loads.

II. Steam consumption and generation

A. Line loss

Based on the assumption that the pipe insulation to be replaced has allowed approximately twice the heat loss of a properly insulated pipe, a savings of 3,336,220 lbs. of steam per annum could be realized.

Line loss

47,304,000 - 3,336,220 = 43,967,780 lbs. per annum

B. Hot water load

Same as Alternative 2 5,734,160 lbs. per annum

C. Process load

Same as Alternative 2 21,708,000 lbs. per annum

D. Heating load

Same as Alternative 2 181,931,499 lbs. per annum

E. Auxiliary load

14% of steam generated 41,575,075 lbs. per annum

F. Summary

1.	Line loss	43,967,780
2.	Hot water load	5,734,160
3.	Process load	21,708,000
4.	Heating load	181,931,499
5.	Auxiliary load	41,575,075
	TOTAL steam generated	294,916,414 lbs. per annum

III. Annual operating costs

A. Fuel oil

Based on 1959 cost of 4.8801×10^{-4} \$/lb. of steam

\$143,922. per annum

B. Water

Based on 1959 cost of 9.5385×10^{-6} \$/lb. of steam

\$ 2,813. per annum

C. Electric power

Based on 1959 cost of 7.5×10^{-6} \$/lb. of steam

\$ 2,212. per annum

D. Operation supplies

Same as Alternative 2 \$ 1,500. per annum

E. Operation labor

Same as Alternative 2 \$ 50,966. per annum

F. Maintenance labor

Same as Alternative 2 \$ 16,687. per annum

G. Maintenance materials

Same as Alternative 2 \$ 6,000. per annum

H. Supervision and clerical costs

Same as Alternative 2 $ 12,768. per annum

I. Office materials

Same as Alternative 2 $ 200. per annum

J. Total operations cost

A + B + C + D + E + F + G + H + I = J

$237,060. per annum

IV. Cost of system

A. Plant $1,890,699.

B. Distribution system $ 442,295.

C. Rehabilitation of insulation

1. Material

Size	Length	Unit Price	Cost
$2\frac{1}{2}$"	62	$0.548	$ 34.
4"	625	0.822	514.
5"	200	0.950	190.
6"	155	1.096	1,156.
8"	460	1.85	851.
10"	205	2.09	428.
12"	345	2.34	807.
TOTAL			$3,980.

2. Installation cost

(1.5)(material cost) = $5,970.

3. Cost of removal of old insulation

2052 ft. @ 14.40$/100 ft. = $295.

4. Total cost of rehabilitation

a. Remove old insulation $ 295.

b. Material cost $ 3,980.

c. Installation cost 5,970.

TOTAL $10,245.

D. Total system cost

A + B + C = D $2,343,139.

V. Fixed costs

A. Depreciation

$\frac{\$2,343,139.}{20 \text{ years}}$ $117,157. per annum

B. Interest

Based on $4\frac{1}{2}\%$ interest for 20 years

$\left(\frac{20 + 1}{2(20)}\right)(0.045)(\$2,343,139)$ $ 55,357. per annum

C. Taxes

$\left(\frac{\$68.54}{\$1000}\right)(\$2,343,139.)$ $160,599. per annum

D. Insurance

$\left(\frac{\$0.044}{\$100}\right)(\$2,343,139.)$ $ 1,031. per annum

E. Total fixed costs

A + B + C + D = E $334,144. per annum